# FOOD PROCESSING AND FOOD PRODUCT DEVELOPMENT OF WATERMELON FRUIT, *Citrullus lanatus* (THUNBERG) MATSUMARA AND NAKAI

By

SIM SUN HUOR

A DISSERTATION PRESENTED TO THE GRADUATE COUNCIL OF
THE UNIVERSITY OF FLORIDA
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

1979

RIJ 5 79 1.1.9.7

To my wife and children

## ACKNOWLEDGEMENTS

The author expresses his heartfelt appreciation to his advisor, Dr. E. M. Ahmed, chairman of his supervisory committee. Without his unfailing help and guidance, this study would have never been completed. His gratitude is also extended to the members of his supervisory committee -- Dr. D. D. Gull, Dr. P. V. Rao, Dr. J. Soule and Dr. S. V. Ting for their valuable advice, help and encouragement.

He also wishes to acknowledge Dr. J. A. Cornell and Mr. W. Offen for aid in statistical designs and analyses. The generous help and encouragement offered by Dr. R. C. Robbins, Dr. R. H. Schmidt, Dr. R. F. Matthews and Dr. J. C. Deng of the Food Science and Human Nutrition Faculty are rightly esteemed. He is particularly indebted to Mr. R. D. Carter and Mr. R. L. Huggart (Florida Department of Citrus, Lake Alfred, FL) and Dr. C. Barmore (AREC-Lake Alfred) for help and advice with concentrating watermelon juice with the TASTE evaporator, and the color study of watermelon-grapefruit mixture. Recognition is also extended to Watermelon Growers Association at Lakeland, Ben Hill Griffin, Inc. at Frostproof, and General Foods Birds Eye Division at Winter Haven for their generous supply of materials needed for this work.

Special personal thanks are extended to Ms. Mary Heisler for her assistance in sample preparation and analyses throughout the research period, and Mr. A. Newton and Mr. L. Donahue for help with the processing

equipments used in his work. He is also grateful to Ms. Nancy Byrd for her sympathy and willingness to assist in difficult times. He greatly appreciated the good friendship of his professors and the graduate students.

He is forever indebted to the Committee for Coordination of Investigations of the Lower Mekong Basin (Mekong Committee) for sponsoring his studies and providing a sustained financial support.

Finally he is deeply grateful to his wife Yane for her extreme patience and devotion, and his children Vissett and Anita for their perfect understanding.

# TABLE OF CONTENT

Page

ACKNOWLEDGMENTS.................................................. iii

LIST OF TABLES................................................. ix

LIST OF FIGURES................................................ xi

ABSTRACT....................................................... xiv

INTRODUCTION.................................................... 1

LITERATURE REVIEW............................................... 3

Watermelon and its Utilization........................ 3

Watermelon Production, Marketing and Storage...... 3
Harvesting, Handling and Market Diseases.......... 9
Composition, Nutritional Value and Utilization.... 10

Fruit and Vegetable Juice Concentration............... 13

Evaporative Concentration......................... 14
Low-pressure evaporators.................... 15
Flash evaporators........................... 18
Freeze concentration.............................. 19

Fruit Beverages....................................... 20

Nutritional and Economic Importance............... 20
Standards of Identity............................. 21
Fruit Punches..................................... 23
Sensory Evaluation................................ 24

Color Enhancement of Grapefruit Juice................. 26

Importance of Color............................... 26
Major Pigments of Pink Grapefruit and their stability................................ 27
Color Enhancement of Pink Grapefruit Juice........ 28

Seed Protein.......................................... 30

Protein Requirement and Assessment of Protein Quality........................................ 30
Utilization of Seed Protein....................... 33

TABLE OF CONTENTS (continued)

Page

Watermelon Seed Protein.......................... 33

Seed Oil............................................. 36

Extraction of Seed Oil........................... 36
Classification of Seed Oils...................... 37
Physical and Chemical Properties of Seed Oils.................................. 38
Watermelon Seed Oil.............................. 40

MATERIALS AND METHODS................................. 41

Preliminary Studies.................................. 41

Gross Composition................................ 41
Proximate Analysis............................... 42
Juice Quality.................................... 42
Brix......................................... 43
Titratable acidity (TA) and pH............... 43
Ascorbic acid content........................ 43
Color........................................ 43
Mineral content.............................. 43

Watermelon Concentrate............................... 44

Concentrate Methods.............................. 44
Freeze concentration......................... 45
Low-pressure concentration................... 45
TASTE........................................ 45
Concentrate Quality.............................. 52
Concentrate Flow Behavior........................ 52
Major Pigment.................................... 53
Chloroform system............................ 53
Hexane system................................ 53

Utilization of Watermelon Concentrate................ 54

Fruit Punch...................................... 54
Bench-top tests.............................. 54
Laboratory and small-scale consumer tests.... 54
Formulation.............................. 54
Testing and analysis of the results...... 54
Grapefruit-Watermelon Mixtures................... 58
Flavor enhancement of white grapefruit juice with watermelon concentrate.......... 58
Color enhancement of white grapefruit juice with watermelon concentrate.......... 59
Color stability and storage study of grapefruit-watermelon mixture.................. 59
Reconstituted juice...................... 59
Frozen concentrate....................... 59
Pasteurized reconstituted juice.......... 60

Watermelon Seed Protein Studies...................... 60

TABLE OF CONTENTS (continued)

Page

Protein Extraction.............................. 60
Proximate Analysis of WPC and Kernel........... 61
Functional Properties of WPC................... 61
Solubility............................... 61
Emulsifying capacity......................
Foaming capacity and stability............ 61
Amino Acid Profile of WPC and Kernel........... 62

Watermelon Seed Oil Studies......................... 63

Oil Content of Whole Seed and Kernel........... 63
Separation and Classification of Lipids......... 64
Fatty Acid Composition of Neutral Lipid and Total Lipid.................................. 64
GLC Analysis of Neutral Lipid.................. 64
GLC Analysis of Total Lipid.................... 65
Physical and Chemical Properties of Seed Oil.... 65

RESULTS AND DISCUSSION................................ 66

Preliminary Studies................................ 66

Gross Composition.............................. 66
Proximate Analysis............................. 66
Juice Quality.................................. 69

Watermelon Concentrate............................. 71

Concentration Methods and Concentrate Quality... 71
Flow Behavior.................................. 73

Major Pigment.................................. 79

Utilization of Watermelon Concentrate............... 84

Fruit Punch.................................... 84
Bench-top test........................... 84
Laboratory tests......................... 84
Small-scale consumer tests................ 99
Grapefruit-Watermelon Mixtures.................. 104
Flavor enhancement of white grapefruit juice with watermelon concentrate........ 104
Color enhancement of white grapefruit juice with watermelon concentrate........ 104
Color stability and storage study of grapefruit-watermelon mixtures........... 111
Reconstituted juice.................. 111
Frozen concentrates.................. 120
Pasteuirzed reconstituted juice....... 130

Watermelon Seed Protein Studies..................... 139

Page

Protein Extraction.............................. 139
Proximate Analysis of Watermelon Seed Protein Concentrate (WPC) and Kernel.......... 139
Functional Properties of WPC.................... 140
Solubility................................ 140
Emulsifying capacity and foaming stability................................ 140
Amino Acid Profile and Protein Quality of WPC and Kernel................................ 144

Watermelon Seed Oil Studies.......................... 146

Oil Content of Whole Seed and Kernel............ 146
Separation and Classification of Lipids......... 148
Fatty Acid Composition of Neutral Lipid and Total Lipid.............................. 148
Physical and Chemical Properties of Watermelon Seed Oil.......................... 151

SUMMARY AND CONCLUSIONS.................................. 159

REFERENCES.............................................. 161

BIOGRAPHICAL SKETCH...................................... 173

## LIST OF TABLES

TABLE Page

1 Treatment combinations.............................. 56

2 Gross composition of 'Charleston Gray' watermelon.......................................... 67

3 Proximate analysis of different parts of watermelon (% w/w fresh weight basis)................ 68

4 Quality of 'Charleston Gray' watermelon juice........ 70

5 Quality of concentrate produced by different methods............................................ 72

6 Color quality of fresh juice and juice reconstituted from watermelon concentrates prepared by different methods....................... 74

7 Mean acceptability scores of fruit punch as influenced by composition and percentage of juice in the punch.............................. 85

8 Parameter estimates and $R^2$ values for quadratic (Q) and linear (L) models................. 88

9 Small-scale consumer tests with 100% (15:1) juice........................................ 100

10 Small-scale consumer tests with 50% (15:1) juice........................................ 102

11 Small-scale consumer tests with 10% (25:1) juice........................................ 103

12 Small-scale consumer tests with A = 100% (15:1), B = 50% (15:1) and C = 10% (25:1) juices............................................. 105

13 Flavor enhancement of white grapefruit juice with watermelon concentrate................... 106

14 Color enhancement of white grapefruit juice with watermelon concentrate................... 108

LIST OF TABLES (continued)

TABLE Page

15 ANOVA of lightness (L), chroma (c) and hue angle ($\theta$) of reconstituted grapefruit-watermelon mixture, as influenced by storage duration (Ti) at 4 ± 2°C.............................. 112

16 Mean lightness (L) value, chroma (c) and hue angle ($\theta$) of reconstituted grapefruit-watermelon mixtures, as influenced by storage duration at 4 ± 2°C............................................... 113

17 ANOVA of lightness (L) value, chroma (c) and hue angle ($\theta$) of grapefruit-watermelon frozen concentrates, as influenced by temperature (Te) and storage duration (Ti)....................... 122

18 Mean lightness (L) value, chroma (c) and hue angle ($\theta$) of grapefruit-watermelon frozen concentrates, as influenced by temperature (Te) and storage duration (Ti)........................... 123

19 ANOVA of lightness (L) value, chroma (c) and hue angle ($\theta$) of pasteurized reconstituted grapefruit-watermelon mixtures, as influenced by can type (C), temperature (T) and storage duration (Ti)................................................ 131

20 Mean lightness (L) value, chroma (c), and hue angle ($\theta$) of pasteurized reconstituted grapefruit-watermelon mixtures, as influenced by can type (C), temperature (T), and storage duration (Ti)........... 132

21 Proximate analysis of watermelon seed protein concentrate (WPC) and kernel........................ 141

22 Amino acid content (g/100 g protein) of watermelon seed kernel and protein concentrate (WPC)............ 145

23 Watermelon seed oil content (%w/w).................. 147

24 Lipid classes of watermelon seed oil................ 149

25 Fatty acid composition of watermelon seed oil (% of total)........................................ 150

26 Physical and Chemical Properties of watermelon seed oil............................................ 152

# LIST OF FIGURES

FIGURE Page

1 Average monthly value per hundredweight (approx. 45 kg) for Florida watermelons during 1973-1977 (Small, 1977)....................... 6

2 Florida watermelon acreage planted and harvested during 1968-1977 (Small, 1977)............. 8

3 Diagram of the ice crusher (A) and basket centrifuge (B) used in freeze concentration.......... 47

4 Diagram of the low-pressure concentration............ 49

5 Photograph of the thermally accelerated short time evaporator (TASTE).................................. 51

6 Space representation of hue angle and saturation index of fresh and reconstituted juice prepared from watermelon.................................... 76

7 Flow behavior of watermelon (65$^{\circ}$ Brix), orange juice (62$^{\circ}$ Brix), 'Honey' tangerine (66$^{\circ}$ Brix) and grapefruit (53$^{\circ}$ Brix) concentrate................ 78

8 Absorption spectrum of a chloroform extract of watermelon lycopene................................. 81

9 Absorption spectrum of a hexane extract of watermelon lycopene................................. 83

10 Quadratic (dashed lines) and linear (solid lines) model contours for 100% juice ...................... 90

11 Quadratic (dashed lines) and linear (solid lines) model contours for 50% juice........................ 92

12 Quadratic (dashed lines) and linear (solid lines) model contours for 20% juice........................ 94

13 Quadratic (dashed lines) and linear (solid lines) model contours for 10% (15:1) juice.................. 96

LIST OF FIGURES (continued)

FIGURE Page

14 Quadratic (dashed lines) and linear (solid lines) model contours for 10% (25:1) juice........... 98

15 Chroma and hue angle vs visual ranking of grapefruit juice..................................... 110

16 Effect of storage duration over a 15-day period at 4 ± 2°C on lightness values of reconstituted grapefruit-watermelon mixture.......... 115

17 Effect of storage duration over a 15-day period at 4 ± 2°C on saturation index (S.I.) of reconstituted grapefruit-watermelon mixture............... 117

18 Effect of storage duration over a 15-day period at 4 + 2°C on hue angle of reconstituted grapefruit-watermelon mixture............................ 119

19 Effect of temperature (Te) and length of storage (Ti) on L value of grapefruit-watermelon mixture..... 125

20 Effect of temperature (Te) and length of storage (Ti) on saturation index of grapefruit-watermelon mixture............................................. 127

21 Effect of temperature (Te) and length of storage (Ti) one hue angle of grapefruit-watermelon mixture............................................. 129

22 Effect of can type (C), temperature of storage (T) and length of storage (Ti) on L value of pasteurized reconstituted white grapefruit-watermelon mixture............................................. 134

23 Effect of can type (C), temperature of storage (T) and length of storage (Ti) on saturation index of pasteurized reconstituted white grapefruit-watermelon mixture............................................. 136

24 Effect of can type (C), temperature of storage (T) and length of storage (Ti) on hue angle of pasteurized reconstituted white grapefruit-watermelon mixture............................................. 138

25 Effect of pH on solubility of watermelon protein concentrate in aqueous buffer solutions.............. 143

26 Chromatogram of fatty acid methyl esters of watermelon seed neutral lipids........................... 154

LIST OF FIGURES (continued)

FIGURE Page

27 Chromatogram of fatty acid methyl esters of watermelon seed total lipid.......................... 156

Abstract of Dissertation Presented to the Graduate Council
of the University of Florida in Partial Fulfillment of
the Requirements for the
Degree of Doctor of Philosophy

# FOOD PROCESSING AND FOOD PRODUCT DEVELOPMENT OF WATERMELON FRUIT, Citrullus lanatus (THUNBERG) MATSUMARA AND NAKAI

By

Sim Sun Huor

March 1979

Chairman: E. M. Ahmed
Major Department: Horticultural Science

Three methods were used to concentrate 'Charleston Gray' watermelons. Freeze concentration, low pressure-low temperature concentration and thermally accelerated short time evaporation (TASTE) were used to produce watermelon concentrates of 28°, 45°, and 65° Brix, respectively. The best quality concentrate in terms of efficiency and overall flavor, color and yield was produced with TASTE. This concentrate showed a pseudoplastic flow behavior.

Fruit punches containing reconstituted watermelon, pineapple, and orange concentrates, citric acid and sugar were formulated with the aid of mixture response surface methodology. The overall acceptance of the products containing 10%, 20%, 50% and 100% juices was tested, using both laboratory and small-scale consumer tests. Results indicated that any juice concentration, containing up to 80% watermelon of the juice mixture could be as well accepted as the others, provided the formulation

was appropriate. Juice containing 100% watermelon and citric acid, with or without sugar added, was not acceptable. The punch containing 10% juice mixture required a 25:1 Brix-to-acid ratio to be acceptable to the panelists.

White grapefruit mixed with 1 to 2% of $60^{\circ}$ Brix watermelon concentrate produced comparable or better color than best commercial pink grapefruit juices. The mixture could be stored, reconstituted, or pasteurized, without significant change in color. Coloration was provided by the major pigment of watermelon lycopene.

Protein concentrate prepared from watermelon seeds contained 65% protein. It possessed good emulsifying capacity. Maximum solubility occurred at pH 10, but its solubility was only 65% at pH 7. Essential amino acid indices for the seed kernel and protein concentrate, using whole hen egg as reference protein, were 73 and 69 respectively.

The lipid fraction of the seed consisted mainly of neutral lipids, with phospholipids and glycolipids comprising only about 1% of the total. The ratio of unsaturated to saturated fatty acids was 4.6:1. The major unsaturated fatty acid was linoleic acid, representing about 63% of total fatty acids present.

# INTRODUCTION

Watermelon is a warm-climate trailing annual requiring a frost-free season to grow and relatively warm and dry weather to develop good quality fruit having high sugar content. Normally, it takes 80 to 120 days to mature fruit (Sackett, 1975) weighing 5 to 20 kg. Premium prices are paid for early crops. Consequently, the major producing areas are concentrated in the South, with Florida being the leading state in total production. The planting date can be as early as December 15 in South Florida, but as late as March 15 and April 15 in Central and North Florida, respectively (Montelaro and Kostewicz, 1974).

Several varieties are grown in Florida. The most important one are 'Charleston Gray', 'Jubilee', 'Crimson Sweet' and 'Smokylee'. They are marketed from April to July, with the bulk of the crop coming in June and July. They are purchased and consumed, with few exceptions, as raw ripe fruit. Northern shippers or distributors pay high prices for Florida watermelons early in the season. Distributors no longer need to send trucks further south into Florida as the season progresses and watermelons become also available in Georgia, Alabama and South Carolina. Consequently, large quantities of watermelon accumulate, resulting in saturation of the market and a rapid decline in price. Price competition is such that it becomes unprofitable in many seasons to harvest, the result being that fruits are left in the fields. This economic abandonment has caused serious concern among farmers and business circles, as well as scientists. Additional watermelon outlets other than the traditional fresh fruit are definitely needed in order to avoid this seasonal wastage of time, effort and profits.

Watermelon juice contains a relatively high amount of sugar. In the Gainesville area, the soluble solids content ranges from 11.4 to 12.4° Brix (Crall, 1971). There is a possibility that the juice might be satisfactorily concentrated and used as other fruit juice concentrates. The rind and seeds, although extensively used in other countries, may be considered here as possible by-products.

The objectives of this research were to (1) prepare watermelon juice concentrate, (2) utilize the concentrate as an ingredient in a fruit beverage, and (3) study the potential utilization of watermelon seeds.

# LITERATURE REVIEW

## Watermelon and its Utilization

### Watermelon Production, Marketing and Storage

Watermelon production in America is concentrated mainly in the South, major producing states being Florida, Texas, Georgia, South Carolina, California and Alabama (Sackett, 1975). Annual production in each state fluctuates, depending on supply and demand, the percentages of the total production (weight-basis) in 1976 being: Florida 38%, Texas 17.2%, Georgia 9.3%, California 7.5%, South Carolina 4.5%, Alabama 4.3%. National production was 2.6 billion pounds, with a total value of 93 million dollars, of which Florida's share was 26 million dollars (USDA, 1977).

Florida is the leading supplier of watermelons to U.S. markets during late spring and early summer. The average shipment for a seven-week period beginning the first week of April was over 50 % of the total domestic shipments between 1972 and 1976. The average dollar value per hundredweight paid for Florida watermelons was, however, lower than the weighted average paid to other produces. This is in spite of the fact that Florida enters the market first with the advantages of the associated higher early season prices (Wall, 1978). Prices decline rapidly until they approximate the break-even costs of production as the season progresses, and the melons begin to ripen in northern parts of the state where 63% of the total crop is grown (Wall, 1978), and in other states. The largest price drop occurs around the middle of the season (Fig. 1). Florida cannot compete because of the longest distance to terminal markets. The alternative in most instances where local markets were also saturated has been to abandon the crop. Crop abandonment varied from year to year and could be significant (Fig. 2), 14,000 acres being unharvested in 1977.

Watermelons cannot be harvested and stored for an extended period of time due to their short storage life. McCoy (1973) recommended storage at 2.2° to 4.4°C and 85 to 90% RH for 2 to 3 weeks. Watermelons are a tropical crop; thus are subject to chilling injury. Extended storage at low temperatures produces rind pitting and loss of color. However, storage at room temperature for 7 days can improve flavor and intensify color (Sackett, 1975). Flavor improvement is probably due to an increase in sugar content during the early period of storage since high quality watermelons are associated with high total sugar content. Other factors responsible for high quality are deep red color and pleasant crisp flesh texture (Porter et al., 1940). Other workers recommended a higher storage temperature of 4.4° to 10°C and a relative humidity of 80 to 85%. Watermelons are subject to decay and internal breakdown at higher temperatures. Melons held 6 weeks at room temperature developed extremely poor flavor. Watermelons decay less at 0°C than at 4.4°C, but tend to become pitted and have an objectionable flavor after 1 week. Watermelon cultivars in Russia seem to withstand cold storage

Fig. 1 - Average monthly value per hundredweight (approx. 45 kg) for Florida watermelons during 1973-1977 (Small, 1977)

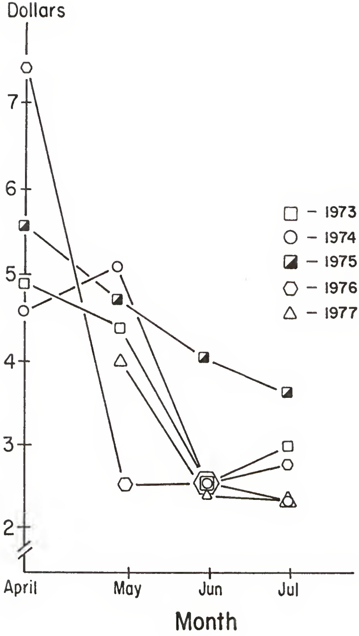
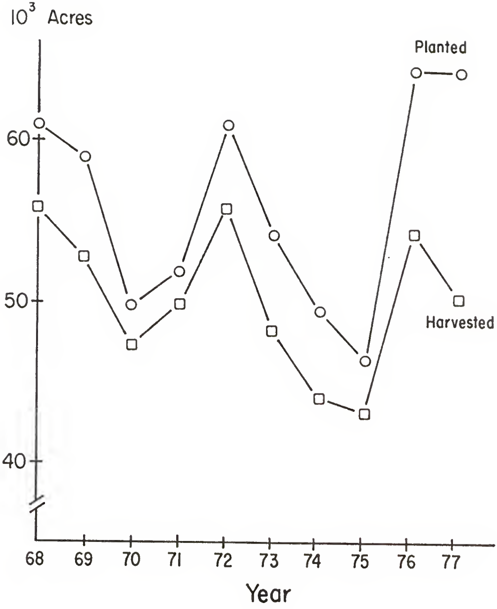

Dollars
7
6
5
4
3
2
April
May
Jun
Jul
Month
□ – 1973
○ – 1974
◪ – 1975
⬡ – 1976
△ – 1977

Fig. 2 - Florida watermelon acreage planted and harvested during 1968-1977 (Small, 1977)


$10^3$ Acres
60
50
40
Planted
Harvested
68
69
70
71
72
73
74
75
76
77
Year

for a longer period of time. Sokol and Vasina (1973) reported successful storage at 0 to 2°C for 1 month and at 2 to 4°C for 2 months; however, there was a slight loss of water from the flesh after 3 months of storage at 4 to 6°C. Sulfitization may further prolong the storage period (Baltaga et al., 1961).

### Harvesting, Handling and Market Diseases

Watermelons must be harvested at a proper stage of maturity in order to ensure consumers' satisfaction. The ability to determine maturity varies among workers and varietal characteristics; therefore, only experienced workers, who are thoroughly familiar with the cultivar of watermelon being harvested should be used. Some of the maturity indications are ground spot color change from white to light yellow, drying and browning of tendrils nearest the fruit and a hollow sound upon thumping. Randomly selecting a few watermelons from various parts of the field, cutting open and testing them are the best tests of ripeness (Montelaro and Kostewicz, 1974). Melons should be cut from the vine with a long stem attached, to allow a second cut if stem end rot treatment is needed. They should be handled carefully to prevent internal flesh bruising and loss of quality, especially in the early morning when fruits are turgid. Harvested melons are stacked no more than six high and hauled in trucks or trailers having a straw bed 6-inch deep in the bottom and padding on the sides (Sackett, 1975).

The major market diseases of watermelons are anthracnose, black rot, fusarium rot, phytophthora rot and stem end rot. There are no control measures besides discarding infected fruits, careful handling to avoid injury and proper control of temperature and humidity (Sackett, 1975).

## Composition, Nutritional Value, and Utilization

The composition of 100 grams of the raw edible portion of watermelon flesh is water, 92.6%; protein, 0.5 g; fat, 0.2 g; total carbohydrate, 6.4 g; fiber, 0.3 g; ash, 0.3 g; calcium, 0.7 mg; phosphorous, 10 mg; iron, 0.5 mg; sodium, 1 mg; potassium, 100 mg; vitamin A, 590 IU; thiamine, 0.03 mg; riboflavin, 0.03 mg; niacin, 0.2 mg; ascorbic acid, 7 mg and a food energy of 26 calories (Watt and Merrill, 1975). A 500-g portion would provide 2950 International Units of vitamin A or about 60% of the recommended daily dietary allowance (RDA), 35 mg of vitamin C or 78% of the RDA, and 2.5 mg of iron or 25% of the RDA of a normal adult (Martin and Coolidge, 1978), but only 130 calories and very little sodium.

Watermelon has been known to Americans for centuries. It remains primarily an outdoor fresh fruit delight despite its popularity as a summertime treat "par excellence" and per-capita consumption has dropped 10% since the period 1948-53 (Anonymous, 1975). Critics attributed this situation as a consequence to the modern life style which tends to encourage people to stay inside air-conditioned rooms and to accept convenience foods more readily.

Little has been written about watermelon utilization. Sackett (1975) reviewed many uses of watermelon. The flesh can be used as a part of a mixed fruit salad. An attractive party dish is made by splitting the melon longitudinally, removing balls of flesh, cleaning out the rind, and filling it with watermelon, cantaloupe and honeydew balls, coconut and berries. A "party centerpiece and portable bar" is improvised by cutting a plug in watermelon, filling it with an alcoholic beverage and sipping the juice with straws. The juice can be used as a base in fruit punch, ices or molded jellies. The rind can be pickled for home use or gourmet products. An insignificant but interesting use of the juice is a beverage for people having kidney problems. Cities such as Rocky Ford, Colorado, Stockdale, Texas, and Atlanta, Texas, were reported to have "watermelon banks," storing either frozen fruit or juice.

Crown Can Co. made the only attempt to industrialize watermelon products in 1942. It produced and marketed canned or bottled single-strength watermelon juice containing about 0.2% to 0.4% organic acid, and patented the product (Yawger, 1942).

Alcoholic fermentation of the juice containing 6.55% soluble solids, predominantly simple sugars (Khattak et al., 1965a), and conversion of watermelon liquor to acetic acid (Khattak et al., 1965b) were attempted on a laboratory scale. These researchers indicated that Saccharomyces ellipsoideus produced larger amounts of alcohol with an efficiency of 71.6 to 77.8% as compared to S. cerevisiae and S. fragilis at pH 4.5. Increasing the sugar concentration from 6.5 to 9.0 or 12.0% improved the fermentation efficiency but a slight decrease in efficiency resulted when the sugar concentration was raised to 15.0%. A. orleanense was most efficient among various acetobacters used to convert watermelon alcohol to acetic acid. Addition of 0.5% potassium biphosphate and 20% apple cider vinegar to the fermented liquor increased both the rate and efficiency of acetic acid fermentation. Watermelon syrup was prepared by boiling the juice to produce a 50 to 65° Brix concentrate. It was considered "just another syrup," the yield probably being too low to compare with corn and sorghum syrup (Webster and Romshe, 1951).

Watermelon is used more extensively in other parts of the world. The following products are made in Russia. Beer was produced from watermelon juice (Sackett, 1975). High grade pectin was extracted from the rind, the yield being 4.65 kg per ton of watermelons or 150-300 kg pectin per hectare of watermelons. Its use in jellies and confection was suggested due to the high quality gel produced. The rind, which contains a high amount of pectin, can be used to replace apple purée in jam production (Baltaga et al., 1961; Pangalo, 1960). Watermelon syrup has been used extensively as a food item in the Soviet Union (Lutochir and Untersuch, 1927). Dietetic juices prepared from watermelon juice mixed with sugar and other fruit juices having high natural acidity were well accepted (Gusina et al., 1971). Its diuretic effect was believed to be associated with its high potassium content (98.6 mg / 100 g of juice) (Gusina and Trostinskaya, 1974). Watermelon juices kept at -18°C and 80 to 90% RH stored well for 1 year but for only 4 months at -12°C (Myskin and Fokin, 1974). Salted watermelon is a popular product. It is brined in wooden vats or barrels or concrete vats containing 5% salt solution or sand impregnated with 5% brine (Sokol and Anokhina, 1973).

Watermelon syrup prepared from red watermelons of Slovak origin has been much praised and considered as a honey substitute in Czechoslovakia (Ivancenko and Tibensky, 1954; Ivancenko and Zajac, 1958).

Soft candied watermelon flesh has been produced in France (Richard, 1971, 1974). Wine has been made from watermelon juice in Egypt, the flavor being improved by the addition of tartaric acid and sugar or grape juice (Akher et al., 1974). The rind is used as pickle, candied peel, or vegetable substitute in Southeast Asian cooking.

Watermelon seeds, which contain no dangerous alkaloids or cyanogenetic glucosides (Oke, 1965; Anonymous, 1916; Fefer et al., 1954) are utilized extensively in Africa and Asia. They are roasted, or dried, with or without being salted and consumed as nuts. Occasionally, the kernels are used as nut substitutes in bakery products. The extracted oil, which is comparable in quality to that of sunflower seed (Anonymous, 1916), is widely used as cooking oil in Africa. The residual cake is fried to make a protein rich cake known locally as "igbalo" (Oyenuga and Fetuga, 1975). Watermelon seeds also contain a useful enzyme, urease. Crude extracts from the seeds, or simply finely chopped seeds provide a cheap and effective means of the detection of blood urea (Ramirez and Monge, 1962; Pequeno, 1963; Khaleque et al., 1964; Singh et al., 1971).

## Fruit and Vegetable Juice Concentration

Liquid food concentration permits economies in packaging, storage and transportation (Heid and Casten, 1961) and reduces microbial spoilage due to lower water activity in the concentrate (Potter, 1973). The most common methods for removing water are fractional crystallization and evaporation. Partial freezing in cold weather is the traditional method for concentrating hard cider to produce an alcoholic beverage known as applejack. Beer and vinegar have also been concentrated by partial freezing (Feinberg, 1964). Solar evaporation of salt brines from sea water and open kettle concentration are familiar methods of evaporation. A lesser known method of concentration is "reverse osmosis," which consists of pumping of liquid foods under pressure against a semi-permeable membrane in a suitable support. This membrane allows the passage of water, but retains food solutes. The process is known as ultrafiltration when only higher molecular weight solutes are retained. The latter technique, in addition to concentrating liquid foods, also modifies the composition of the concentrate by altering the ratios of solid components retained. Ultrafiltration is a commercial process for recovering whey protein and modifying the composition of cheese whey (Potter, 1973).

This review is concerned with fruit and vegetable juice concentration methods used in the food industry. These methods can be divided into two broad classes, evaporative concentration and freeze concentration.

## Evaporative Concentration

Evaporation of water is achieved by heating the juice with steam. Certain fruit and vegetable juices are heat sensitive or thermolabile, thus requiring low-temperature processing or brief exposure to high temperature in order to avoid objectional quality changes. Temperatures lower than those required to evaporate water under atmostpheric pressure can be utilized to concentrate juices by reducing the pressure inside the evaporator. Evaporators may be connected in series to form a multi-stage unit (Potter, 1973). A multiple-effect evaporator is obtained if steam is used more than once and theoretically, a double-effect or triple-effect evaporator uses half or a third as much steam than a single-effect evaporator (Farrall, 1976).

The most common types of fruit and vegetable juice evaporators are thin-film evaporators, plate-type evaporators, low-pressure evaporators (or vacuum evaporators), and flash evaporators. This review is concerned only with low-pressure and flash evaporators.

### Low-pressure evaporators

Evaporation takes place when there is a temperature difference between the heating medium and the boiling juice. This temperature difference can be achieved by either raising the temperature of the heating medium or lowering the boiling temperature of the juice. The latter case is the choice for heat-sensitive materials. It can be accomplished by reducing the pressure above the boiling liquid. A simple low pressure evaporator is obtained by sealing a heated open kettle and removing the vapor with a vacuum pump.

Commercial low pressure evaporators are sophisticated in design and operation, common sequence of flow in the concentration of fruit and vegetable juice at reduced pressure and lower temperature being described. High pressure steam is injected into the evaporator and allowed to escape through a large steam ejector or "hog" jet to establish initial vacuum. Preheated juice is pumped or sucked into the heat exchanger after the desired degree of vacuum is reached, then steam is admitted into the steam chest and boiling begins. Vapors are separated and removed rapidly and continuously in order to maintain the vacuum. Once the juice boils and vapor removal starts the vacuum is self-sustaining and the "hog" jet may be turned off. Several vacuumized vessels may be installed in series so that the juice concentrated moves from one vacuum chamber to the next and becomes progressively more concentrated in stages. Since heat will flow only "down hill," from high temperature to low temperature, the evaporating juice must boil at a lower temperature in successive stages, thus requiring progressively lower pressures (Feinberg, 1964). Hot vapor arising from the first stage is used to heat the second stage, the vapor from the second stage heats the third, etc. Such a system is called a multiple-effect vacuum or low pressure evaporator and permits maximum utilization of heat energy. However, there is a practical limit to the number of effects that can be economically used for each product. Some volatile flavor compounds are lost with the evaporating water, although the system may operate at 27°C or lower. These volatile essences can be recovered and returned to the cool concentrate (Potter, 1973).

Operating conditions, recovery of volatiles, and product treatment before, during, and after concentration vary with the specific juice and the intended use of the concentrates.

Orange juice is extensively concentrated for the manufacture of frozen concentrates, beverage bases, confectionery ingredients and other uses in foods. The extracted juice is strained, flash heated to deactivate the natural pectinesterase present. The active enzyme is responsible for gelation of orange concentrate, and 'cloud' separation in the reconstituted juice. Flash heating is also necessary in order to reduce microbial population. To minimize flavor change, the hot juice is flash cooled into a vacuum or, less commonly, in a surface-type heat exchanger, before being concentrated to 58% solids at temperatures below 27°C. Single strength juice plus recovered flavor and essential oils from the peel are added to cut back the concentrate to a minimum of 44.8% or up to a maximum of 47% (Fla. Dept. Citrus, 1979a) and compensate for the loss of volatile flavor during concentration. Concentrates from different batches may be added along with cut-back juice, and blended with the original 58° Brix concentrate to provide a product of uniform quality. Concentrate is then frozen and stored in gas tight containers under nitrogen or carbon dioxide. Reconstituted orange juice is obtained by adding 3 volumes of water to one volume of concentrate (Heid and Casten, 1961; Berry and Veldhuis, 1977). Institutional packs of 4 + 1 frozen concentrated orange juice require a minimum of 53.8%, and a maximum of 56% (Fla. Dept. Citrus, 1979b).

Tomatoes are chopped and quickly heated to inactivate enzymes, disperse and stabilize suspended colloidal materials and color bodies. The seeds and cores are separated in pulpers and finishers. The puree is fed to the concentrators. Triple-effect evaporators are capable of concentrating tomato juice from an initial 6% to a final concentration of 30% solids (Potter, 1973). Thin-film evaporators are more extensively used to produce higher solids paste, up to 50%. Much tomato puree and paste are produced in California, the leading producer of tomato products (Heid and Casten, 1961).

### Flash evaporators

The liquid is preheated in a conventional heat exchanger to about 99°C, and pumped through a vertical or diagonal tube where clean "culinary" steam is injected to superheat the liquid to 121°-149°C in a 0.5 second or less. The superheated liquid flows down a single-pass heat exchanger when it quickly flashes into a mixture of vapor and liquid from which the concentrate is separated. Such systems were used commercially in the concentration of grape juice, apple juice, and tomato purée (Nowlin and Henwood, 1954; O'Connell, 1954).

Another type of flash evaporator is commercially known as the Thermally Accelerated Short-Time Evaporator (TASTE). Juice is preheated in a conventional heat exchanger to about 90°C, then flashed through a series of down-flow, single-pass evaporators with progressively lower pressures. This evaporator is used by several citrus juice concentrators (Feinberg, 1964). A modern unit used in the concentration of citrus juice in Florida can be described as follows.

The general use of heat treatment showed that brief exposures to relatively high temperatures did not significantly affect product quality (Berry and Veldhuis, 1977), therefore permitting a shorter exposure time for enzyme inactivation and microbial destruction, and reducing deterioration in quality. Cook (1963, 1964) designed the original unit using this concept of high temperature-short time. It has 7 stages and 4 effects plus a flash cooler. The juice passes through each stage once and is concentrated to 65° Brix in about 3 minutes. The juice temperature starts at 21°C at feed-in, accelerates to 40°

and 96°C at 1st and 2nd stages where the juice is evaporated, pasteurized and enzyme-stabilized at the same time, then decreases gradually to 40°C at the 7th stage, and to 16°C at the flash cooler. The TASTE unit is so efficient that it made older citrus concentrators "obsolete in many ways" (Carter, 1965).

The TASTE advantages over low temperature vacuum evaporators are improved product quality, 85% reduction in clean-up time, 66% reduction in steam requirement, lower power requirement, 85% reduction in space, and 18% savings in construction costs (Carter, 1965). Florida citrus processors have been replacing their older units with TASTE, which now exceeds all other units combined in total number installed (Berry and Veldhuis, 1977)

### Freeze Concentration

The simple method of concentrating a juice by freezing it in a container and then draining off the syrup has been used for many years, and is still used at present by farmers living in cold climates. This process, although requiring little equipment and no power for refrigeration is slow, demands much labor and does not allow for product standardization.

Modern technologies utilize mechanical refrigeration to freeze out the water in the juice and physical processes such as centrifugation to separate ice crystals. It requires less energy to freeze than to evaporate the same amount of water. However, this is only one step of the total process. More energy is required to crush the frozen block, centrifuge the ice particles, and recover the soluble solids and suspended matter entrapped in ice, resulting in a high processing cost

(Salunkhe and Bolin, 1974). The main attribute of freeze concentration is maximum flavor retention. However, modern essence recovery system has made freeze concentration less attractive. Furthermore, modern multi-effect evaporators are very efficient, and provide a rapid method of concentrating the juice. Consequently, commercial efforts to modify and improve freeze concentration have been abandoned (Berry and Veldhuis, 1977).

## Fruit Beverages

### Nutritional and Economic Importance

Most people, regardless of their knowledge about nutrition, look upon fruits and vegtables as important foods for good health. They provide most of the vitamins and minerals, but the least amount of fat and calories. In 1971, over 90% of ascorbic acid, one-half of vitamin A, about one-third of vitamin B6, about one-fifth of thiamin and niacin, one-fourth of magnesium and one-fifth of iron in the food supply were provided by fruits and vegetables (Rizek et al. , 1974). Juices in one form or another are consumed universally (Thorner and Herzberg, 1970). Their importance for agriculture and public health is such that the "International Federation of Fruit Juice Producers," was created in 1948 to oversee their production, utilization and distribution (D'Eaubonne, 1965).

The popularity of fruit juices in the United States stems from tradition or habit and knowledge of their value. For example, orange juice is consumed as part of breakfast and for its nutritional and therapeutic value. Development of fruit juices as beverages in

America dates back to 1860, or earlier. They were recommended by physicians and "taken to quench thirst and convey nourishment to the blood" (Holbrook, 1875). Holbrook's interest was primarily to improve the nutritional status of his patients. He published formulas for preparing beverages from many fruits, some of which were apple tea, blackberry drink, cherry drink, cranberry drink, currantade, fig water, ginger drink, gooseberry water, grape drink, orange/lemonade, lemonade, pineapple/lemonade, strawberry drink and tamarind water. (Woodroof and Phillips, 1974).

## Standards of Identity

Fruit beverages are commercialized under a variety of names - fruit drinks, juice drinks, breakfast drinks, ades, nectars, treats, etc. Whatever the case may be, they are generally mixtures of fruit juice with sugar, coloring ingredients, flavoring agents, and water, and sometimes fortified with vitamin C. They may be pasteurized, sterilized, canned, bottled, frozen, or preserved with chemicals, and used straight, diluted or concentrated. Ingredients added are listed in order of their predominance, and, in some cases, the purpose or function of each additive is given.

There are no national standards of identity and no clear understanding of what constitutes a fruit drink, ade, nectar, or other drinks. Fruit juices and fruit drinks closely resemble each other in outward appearance on grocery shelves; hence shoppers must keep a sharp eye on the labels to keep from mixing them up (Woodroof and Phillips, 1974).

The Food and Drug Administration and National Juice Products Association recommend the declaration of the percentage of fruit juice in the drink. The regulations for orange juice drink were proposed in 1972 (Federal Register), but were stayed in 1973 (Federal Register). They are still stayed at the present time. However, some industries in Florida are following the proposed guidelines for orange and other fruit drinks (Carter, 1979). The guidelines adopted specify the types of drink in accordance with the designation, the juice content, and the natural juice solids. Orange blend, under the designation (D) 146.159, must contain 70-95% orange juice (OJ), and 8.26 to 11.2% natural orange juice solids (NOJS); orange juice drink, D 146.155, must contain 35 to 70% OJ and 4.13 to 8.26% NOJS; orange drink, D 146.161 must contain 10 to 35% OJ and 1.18 to 4.13% NOJS; orange flavored drink, D 146.165, must contain 0 to 10% OJ, and 0 to 1.28% NOJS. The percentage of orange juice in the product is determined on the basis of orange juice soluble solids, as in the national standards (Federal Register, 1973; CFR, 1977).

National standards, which do not require the separation of orange juice drinks into categories or types, however require a statement of the percentage of orange juice contained in the product. This percentage must be declared in 5% increments not greater than the actual percentages of orange juice in the product. When it is greater than 0 but less than 5, the statement must be "less than 5% (Anonymous, 1978).

Individual fruit juices and sometimes their mixtures have rigorous standards (e.g. grapefruit and orange juice), the basic requirements being mandatory under Federal and State Food and Drug laws. In addition, the products are subjected to quality grading by the United States Department of Agriculture and in Florida by the Florida Department of Agriculture and Consumer Services. Four distinct grades for juices have been established as follows: (1) U.S. Grade A or U.S. Fancy, (2) U.S. Grade B or U.S. Choice, (3) U.S. Grade C or U.S. Standard, and (4) Substandard. Each grade is assigned a range of scores obtained by adding all the scores given to such factors as color, flavor, defects. A perfect score is 100 points (Thorner and Herzberg, 1970).

### Fruit Punches

Punches are beverages made from a combination of fruit or berry juices with water, sugar, and other additives. The most popular are made from tropical fruit juices, such as passion fruit, papaya, and guava. A widely marketed product is the Hawaiian Punch, which consists of pineapple, papaya, passion fruit, guava, and citrus juices (Thorner and Herzberg, 1970). Fruit punches are known as squashes, cordials or crushes in Great Britain and other countries such as Australia, India, New Zealand, and South Africa which have inherited British traditions (Kefford and Chandler, 1977).

Fruit punches are a very popular product in the United States. They seem to play a central role in such important occasions as birthday parties, Christmas celebrations, graduation parties, picnics, springtime welcomes, sweetheart affairs and wedding celebrations. Formulations of some of these special punches are published by Tressler and Woodroof (1976).

## Sensory Evaluation of Beverages

Sensory evaluation is concerned with human evaluation and measurement of physical stimuli. Modern instruments such as the gas chromatograph have been used successfully to identify and classify odors. However, the mechanisms of sensory perception within the human body are still considered to be the most delicate and readily available for these evaluations (Thorner and Herzberg, 1970).

Sensory perception involves the senses of taste, smell, touch, and sight. These senses are influenced by many external and internal factors, which in turn influence sensory evaluations. While it is possible to standardize external or physical factors such as testing area, testing setup, lighting, sample preparation, serving temperature, utensils, quantity of sample, coding and order of presentation, and rinsing (Larmond, 1973), it is impossible to control internal factors such as sex, age, origin, ethnic group, income, and physiological conditions, which vary from one person to another. The use of block designs in multiple comparison experiments results in the elimination of variation due to panelists.

The inability of a panelist to express a preference when comparing 2 treatments may be due to the fact that his/her sense of perception is not sharp enough to detect the existing difference. For this reason, Rao and Kupper (1967) proposed a model which incorporated a "tie parameter."

Among other factors of importance in the experimental design for sensory evaluations are the number of samples and the panel size. The number of samples per session depends upon:

(1) the nature of the product being tested. No more than 6 ice cream samples should be evaluated because of the low temperature of the product (Larmond, 1970); however, 18 samples of squash could be tasted without decrease in efficiency (Kramer et al., 1961); on the other hand, only 2 or 3 beer samples are recommended (Bengtsson and Helm, 1946), while up to 7 samples of frozen concentrated orange juice could be tested successively (Tomkins and Pratt, 1959);

(2) the experience of the taster--a master panel or a trained panelist can evaluate more samples than an untrained panelist;

(3) the amount of time and resource available;

(4) the type of tests.

A consumer test can accommodate fewer samples per person, due mainly to the difficulty in controlling testing conditions in a public place, Kefford and Christie (1960) considering 2 as the maximum number. The number of judges needed in a given experiment depends on several factors. Generally, the larger the panel, the more reliable is the result. However, the panel size is often limited by the costs of materials and the availability of acceptable panel members (Cartwright et al., 1952). There is no agreement as to what constitutes the right size of panel. The committee on sensory evaluation of the Institute of Food Technologists (Anonymous, 1964) based its recommendations on the degree of training of panelists. The number should be 3 to 10 for trained, 8 to 25 for semi-trained, or at least 80 untrained judges for various types of sensory methods.

## Color Enhancement of Grapefruit Juice

### Importance of Color

Food quality is determined by 3 major factors, color, flavor and texture. Color, in most cases, plays the key role in influencing the decision of the purchaser to buy or reject a product.

Pangborn (1967) acknowledged the importance of color with the following statement: "To a large extent man recognizes, discriminates, and selects nutrients with the eye. Through conditioning and association, he expects an item of a certain shape and color to have a specific odor, taste, and texture. In foods, colors are identified with previously experienced quality and serve as instant indicators of good or bad, according to the product and its intended use." Francis and Clydesdale (1975) were even more categorical in their opinion about color: "... if the color is unacceptable, there may be little point in considering the flavor and texture."

In practice, color has been used in judging variety and maturity of citrus fruits (Huggart and Petrus, 1976), and many other fruits and vegetables. It is also used by the United States Department of Agriculture to establish standards for grades of agricultural products. This grading system allots up to 20 points for the color of canned grapefruit juice (USDA, 1968), and up to 40 points for the color of frozen concentrated grapefruit juice (USDA, 1970) out of a total possible of 100 points. It accords further importance to color by applying a "limiting rule." For example, the color of grapefruit juice is classified into 3 grades: A, B, and Substandard (SStd). If color falls into classification B, the product may not have a grade higher than the U.S. Grade B regardless of the total score for the product. The same is true for SStd classification. If its color falls in this category, the product may not be graded above SStd regardless of the total score for the product.

## Major Pigments of Pink-Grapefruit and their Stability

Lycopene (red) and beta-carotene (yellow) were identified as major pigments of red and pink grapefruit, while zeta-carotene (pale yellow), and phytofluene (colorless) were predominant in 'Marsh' white grapefruit (Huggart and Petrus, 1976).

Lime et al. (1954) reported that best color of 'Ruby Red' grapefruit in Texas occurs only for a short period after the fruit has passed maturity. The same observation on red and pink grapefruit was made in Florida by Ting and Deszyck, (1958) and Oberbacher et al. (1960) who reported color change from pink early in the season to yellow or yellowish pink later in the season, and associated it with the change in the ratio of lycopene to beta-carotene. Meredith et al. (1974) showed that the high ratio of lycopene to beta-carotene early in the season was responsible for the red appearance in the flesh of 'Redblush' grapefruit in Texas. This red appearance changed to yellow due to a rapid loss of lycopene as the season progresses.

The flesh of grapefruit might be deep pink or red at the time of processing, but the extracted juice, although distinctly pink, is described as being pale, because the red-colored carotenoid is embedded in the rag and pulp of the fruit (Huggart and Ting, 1970). The juice color is provided by the juice sacs (pulp) which remain suspended in the juice. Attractively colored juices may also turn dull or brown when stored under adverse temperatures (Berry and Veldhuis, 1977).

The juice from mature pink or red grapefruit has a faded color, and when canned along or mixed with white grapefruit juice in proportions greater than 10 percent, produces a juice having a brown, non-descript color which falls below U.S. Grade A specifications (Huggart and Ting, 1970).

## Color Enhancement of Pink Grapefruit Juice

Studies attempting to resolve the problem of preparing and storing an attractive canned red and pink grapefruit juices were initiated in Texas as early as 1951 (Lime et al., 1954). Lime and Griffiths (1960) fortified poorly colored juices by adding highly colored red grapefruit pulp recovered early in the season. Pulp content must be controlled, however, due to the presence of bitter compounds, naringin and limonin, and the tolerance limit of pulp allowed in the juice. Huggart and Ting (1970) noted the amount of pulp used to produce a good color in late season juices raised the suspended solids content to 12.5% which exceeds the 10% limit for U.S. Grade A grapefruit juice. Dougherty and Fisher (1977) further reported that lower flavor scores of grapefruit juice were highly correlated with high content of limonin and naringin.

Lime et al. (1958) suggested the use of graphic methods relating pulp content to color scores and naringin level to monitor juices of colored grapefruit juices at different stages of maturity. An attractive red grapefruit juice may be produced through proper selection of highly colored grapefruit, judicious blending, finishing and storage. The recent development of 'Star Ruby' grapefruit in Texas may contribute to the development of a successful product (Berry and Veldhuis, 1977).

The major pigmented grapefruit varieties in Florida are 'Ruby', 'Thompson' and 'Foster'. Pink color develops in the 'Ruby' juice starting in August, becomes bright pink in September and October, then changes to yellowish-pink in November and December, and yellow chamois in January. 'Thompson' and 'Foster' juices parallel the change in color of those of 'Ruby' but their best color shows only the slightest tinge of pink, which rapidly changes to the chamois yellow color of the juice from mature fruit (Huggart and Ting, 1970). These workers, feeling that the homemaker might expect the standardized Florida canned 'Ruby' to have the same color as that of fresh fruit flesh, attempted to standardize 'Ruby' juice accordingly. They used lycopene extracts from 'Ruby' grapefruit pulp and rag, FD & C Red No. 2 and Yellow No. 5, and a synthetic carotenoid, Hoffman-LaRoche Roxanthin (R). They found that the addition of lycopene extract produced an orange colored juice, which changed rapidly to yellow. However, the juice sacs stored at -15°C changed slightly to a yellower color. Roxanthin (R) produced an acceptable yellowish tomato red color. Mixtures of the soluble or insoluble forms of Red No. 2 and Yellow No. 5 produced colors that closely resembled that of 'Ruby' grapefruit juice. It is noted that Red No. 2 has been delisted by FDA, and that the fate of Yellow No. 5 awaits further testing (Weisler, 1975; Brittin, 1976).

Huggart and Ting (1970) further evaluated the effects of storage temperatures (26.7° and 0°C) and can types (enamel and tin) on the appearance of the standardized juices. Juices packed at 26.7°C in enamel cans and standardized with FD & C insoluble colors retained good appearance for 3 months before browning; juice showed slight browning with addition of Roxanthin (R). Samples packed in tin and standardized with Roxanthin (R) faded slightly in 6 months while those standardized with FD & C soluble or insoluble colors lost their color within one week. Juices packed in enamel cans and standardized with Roxanthin (R) retained their original color after 7 months of storage at $0^{o}C$, whereas juices with soluble colors faded slightly. Similar samples packed in tin and standardized with Roxanthin (R) retained their original color. Samples lost their color with soluble or insoluble colors.

## Seed Protein

### Protein Requirement and Assessment of Protein Quality

Proteins are needed for formation of new body tissue, maintenance of body structure, production of compounds essential for normal body functions, regulation of water balance, maintenance of blood neutrality and supply of energy (Martin and Coolidge, 1978). The amounts of food proteins required per unit body weight depends on (1) the quality of the proteins, which is largely determined by the kinds and proportions of the essential amino acids they contain, as compared to a reference standard, which is usually whole hen egg protein, and (2) the efficiency of their utilization. The standard protein is considered as an ideal protein containing all the essential amino acids in proper proportions and is 100% utilized (Jansen, 1972).

The most common approaches to protein quality estimation use biological and chemical methods, both having limitations. The most widely used biological methods are based on rat feeding assays and include protein efficiency ratio (PER), biological value (BV) and net protein utilization (NPU).

The PER method which originated with Osborne et al. (1919), is the official method for estimating protein quality in Canada and the United States. It consists of feeding weanling rats a diet containing 10% of the test protein for 28 days and calculating the PER as the ratio of the weight gain to the weight of protein eaten. Another group of rats fed a diet containing reference casein acts as a control, and the PER is calculated as before. The average PER of the test protein is multiplied by a correction factor ( $\frac{2.5}{\text{PER of casein}}$ ) to give the final value (AOAC, 1970). The shortcomings of this method are numerous. The PER calculation is based on weight gain only and makes no allowance for maintenance, thus penalizing poor quality protein, because a PER of zero (no growth) does not indicate zero nutritive value. The PER underestimates the quality of excellent protein by using a single and high level of protein (10%). The PER is not proportional to nutritive value, and therefore cannot be used to estimate available protein or to calculate protein requirements. Interlaboratory variation cannot be controlled due to uncontrollable variation in rats, environmental conditions, etc. (Hegsted, 1977). Furthermore, the 28 day test is too long for routine testing (McLaughlan, 1974).

The BV method was developed by Mitchell (1924) for use with growing and adult rats. It was based on the nitrogen gained or lost by an animal as determined by an analysis of its food, feces, and urine. The BV is mathematically defined as a ratio of nitrogen retained to nitrogen absorbed. This method is tedious and prone to cumulative errors. Precision of the method is affected by incomplete separation of urine, feces and food (Miller and Lachance, 1977).

The NPU, like BV, is an estimate of nitrogen retention, but does so by measuring the difference between the body nitrogen content of young rats fed no protein and those fed a test protein. The ratio of this value to the amount of protein intake is the NPU, which is defined as the "percentage of the dietary protein retained" (Hegsted, 1974). It has all the faults described for the measurement of BV (Hegsted, 1977).

Chemical evaluation of protein quality was first proposed by Block and Mitchell (1947). They used the essential amino acid content of whole egg as the standard of reference. The chemical score (CS) was calculated as the relative percent of the limiting amino acid per gram of test protein nitrogen as compared with the same amino acid in egg protein. The CS scores correlated well with biological values of thirty-seven protein foods fed to rats (Milner et al., 1978) and have been used widely.

Recently, the term "amino acid score" (AAS) has been introduced. It is defined as the percentage of amino acid in 1 g of test protein relative to the amino acid in 1 g of reference protein (Pike and Brown, 1975). The lowest score obtained by any amino acid may be used to evalute protein quality and therefore may be considered as equivalent to CS. The essential amino acid index (EAAI) is based on the relationship between the essential amino acid content of a test protein and that of whole-egg protein (Oser, 1965). The correlation between EAAI and various biological tests is high (Stillings and Hackler, 1966; Hackler et al., 1967). Chemical tests therefore have a potential practical application. They are fast, less tedious, require less space, and can identify the limiting amino acid in a single assay. Their main drawbacks are as follows. Their calculation is based on complete digestion of the test protein with acid and therefore make no provision for indigestibility of certain amino acids in the body. Chemical tests consider only essential amino acids, but not others which may also serve important biological functions. Toxic or undesirable substances such as trypsin inhibitors, which affect the value of the test protein, are not considered. Furthermore, problems due to amino acid imbalance are disregarded (Milner et al., 1978).

### Utilization of Seed Protein

Seed proteins in the form of isolate, concentrate or flour, have been increasingly utilized by the food industry. One of the most successful and widely accepted seed proteins is soybean. It is used in many parts of the world in products ranging from beverages, soups, whipped toppings, frozen desserts, gels, macaroni, tofu, bakery products and meat emulsions, to simulated meat (Wolf and Cowan, 1975). This successful utilization of soybean protein depends largely on the knowledge of the functional properties such as solubility, foaming capacity, foam stability, emulsifying capacity, whippability, binding ability, gelation, viscosity, water holding capacity, and fat absorption (Ahmed and Schmidt, 1979). Protein functional properties were amply reviewed by Kinsella (1976).

### Watermelon Seed Protein

Few fundamental studies on watermelon seed protein have been reported in addition to the general utilization of watermelon seeds as nuts. Watermelon seeds belong to a group of lesser known oilseeds (Umoh and

Oke, 1974; Stafford et al., 1978), the best known being soybean of which considerable information on processing, protein extraction and product development is available.

A group of workers in Nigeria noted that oilseeds have high amounts of protein of good quality, but are high in fiber and therefore not very useful for monogastric animals and humans. They actively investigated the nutritive value of watermelon seeds and other lesser known oilseeds to find a cheap source of protein and improve the nutritional status of the Nigerian people, especially that of young infants whose diet relies heavily on starch roots and tubers. Malnutrition usually develops in this group after weaning due to dependency on bulky low protein staple foods, which exceed the capacity of the infants to ingest in order to meet their requirement of protein (Stafford and Oke, 1977).

Oke (1965) reported that Nigerian watermelon seed kernel contained about 32% crude protein. Umoh and Oke (1974) compared the nutritive value of 3 lesser known oilseeds, watermelon, locust bean and African mango, by feeding studies with rats. They were equally highly digestable (87 to 99%). However, watermelon seeds had the highest protein efficiency ratio (PER). Oyenuga and Fetuga (1975) analyzed the amino acid content of watermelon seed meal, and computed their chemical scores, using whole hen egg as reference protein. Lysine and methionine found to be in shortest supply while threonine was marginal. The trypophan content (2.21 g / 100 g protein) was higher than in most other plant protein sources. Rat feeding studies confirmed that lysine was most limiting, followed by methionine and threonine. Oyenuga and Fetuga (1975) further demonstrated that frying the whole and defatted watermelon seed meal did not affect protein content nor its digestibility. Digestibility of the raw and fried whole and defatted meal was high, 91 to 93%, and was comparable to that for soybean meal, 91.7%, but lower than for whole egg, 98.8%. Stafford and Oke (1977) isolated proteins from watermelon, locust bean, and walnut seed meals, using alkaline and saline extraction procedures. Protein contents of concentrates were 73.7% and 82.5%, respectively, for watermelons, 39.6% and 80.4% for walnut, and 60.0% and 71.3% for locust bean. The limiting amino acids were lysine for watermelon with a chemical score (CS) of 57, and methionine for locust bean (CS 28) and walnut (CS 27). Stafford et al. (1978) further evaluated the digestibility of these protein concentrates by in vitro digestion and rat feeding trials. Watermelon was most highly digestable, 97%, with pepsin followed by pancreatin. Locust bean gave the highest digestibility, 96.3%, with rats, while walnut and watermelon were similar, 87.2% and 88.1%, respectively. Watermelon gave the highest PER, 2.40, almost approaching the protein standard, 2.50, followed by locust bean, 1.81. These workers also reported the minimum solubility of watermelon seed protein concentrate (WPC) in Tris buffer at pH 5 and pH 8. They further enriched the traditional weaning formula "Ogi" or maize gruel with WPC. The protein content of the original formula with 10% WPC added increased from 6% to 12%, without change in color, smell, taste or consistency. Protein content of the formula would be tripled, if 20% WPC were used, and the bulky formula that the child needs to consume to provide adequate nutrition would be reduced to an acceptable volume. The WPC still contains a good quantity of linoleic acid; thus the enriched formula would provide also essential fatty acids and calories in addition to protein. "Ogi" is not only popular with Nigerian weaning infants, but also with adults, who consume it as a breakfast food. Adults would also improve their intake of protein and essential fatty acids by eating enriched "Ogi."

King (1941) indicated watermelon seed was about equally digestible as pumpkin seed, 92%. The biological values were 73 for watermelon and 63 for pumpkin. Wang (1940) reported a crystalline protein could be extracted from watermelon seeds.

## Seed Oil

### Extraction of Seed Oil

Seed oil can be extracted by cold pressing, hot pressing, or solvent extraction. Cold pressing consists of applying pressure on seeds containing high amounts of oil such as sesame, peanut and olive. Crude extract of sesame and peanut oil have a pleasant nutty flavor, and need no further processing. This type of oil extraction is not efficient. Hot pressing consists of pressing the seed meal residue left by cold pressing, in a hydraulic press, or a continuous screw press or expeller, which can develop pressures up to 15 tons, leaving only about 2 to 4% oil in the meal. Such presses develop excessive heat and cause darkening of the oil, and protein denaturation. A compromise method known as "prepress-solvent method" was introduced to allow partial removal of oil by pressing and complete oil removal with solvent extraction, without adverse effects on the oil. Solvent extraction removes practically all the oil from the seeds. It is required for seeds containing insufficient amounts of oil to make pressing feasible. The seeds are usually treated by flaking or cooking to increase exposure to the solvent or increase solvent penetration. The solvent used is usually hexane, which is removed by evaporation. This also removes certain flavors from the oil. Oils having desirable natural flavor, such as olive, cannot be treated by this method (Weiss, 1970).

### Classification of Seed Oils

Seed oils and other fats and oils are traditionally classified according to their iodine numbers into nondrying, semidrying and drying oils, mainly on the basis of their suitability for use in paints. This system of classification is not rigorous. For example, soybean oil was classified as semidrying, but is used widely in paints and varnishes, because of its good drying property (Ecky and Miller, 1954). Furthermore, this drying property can be modified by hydrogenation or dehydrogenation. A more instructive classification is needed. Fats and oils are classified from the standpoint of food and industrial application on the basis of their content of fatty acids and group characteristics (Swern, 1964b; Dugan, 1976). For example, the lauric acid group (coconut oil is the most important) is distinguished from other fats by the high content of lauric acid (40 to 50%). Their distinctive characteristics combine a low degree of unsaturation, and relatively low melting point due to the low molecular weight of their acids. They are valuable edible fats for this reason. The oleic-linoleic acid group consists primarily of oleic and linoleic acids. The oils of this group are of vegetable origin. They are highly unsaturated, and in most cases, the saturated fraction represents less than 20% of the total. They are the most widely used and most adaptable oils. They can be hydrogenated to produce plastic fats of any degree of hardness, and are excellent edible oils. They contain essentially no linolenic acids or more highly unsaturated acids, thus are least susceptable to flavor reversion. Representative members of this group are cottonseed, peanut, sesame, corn, sunflower, safflower, olive, and palm oil. The linolenic acid group contains relatively high amounts of linolenic acid (21 to 24%), and comprises linseed, perilla, soybean and hempseed. They are not considered as desirable edible oils with the exception of soybean, due to their tendency toward reversion.

### Physical and Chemical Properties of Seed Oils

Physical and chemical properties provide valuable information for product identification, standardization and development. Some of the most important properties are refractive index, specific gravity, unsaponifiable matter, saponification number, iodine value and free fatty acid content.

The refractive index of oil is constant within a certain range and therefore is used in identification of oil (Pomeranz and Meloan, 1971). It increases with increasing chain length or unsaturation of fatty acids in the glycerides. It correlates with the iodine value, which is a measure of the degree of unsaturation in a fat, and can be used as a control procedure during hydrogenation (Dugan, 1976). It is temperature dependent; hence the refractive index (n or R) used must have a number in the superscript indicating the number of degrees Celsius.

Specific gravity is also a factor in the standard of identity of an oil. Since it compares the relative mass of an oil at a given temperature t to the mass of equal volume of water at t', the specific gravity is expressed as sp. $gr._{t'}^{t}$, with t and t' in $^{o}C$.

Unsaponifiable matter is found dissolved in fat or fatty acids. It is the fraction that cannot be saponified by potassium hydroxide and includes sterols, higher alcohols and some hydrocarbons. The unsaponifiables combined with moisture and insoluble materials form a group known as MIU (moisture, insoluble, unsaponifiable), which is used widely in trading rules (Rodeghier, 1955), and are considered as impurity. The MIU is valueless with the exception of anyone interested in recovering tocopherol.

The saponification value is an indication of the average molecular weight of fat. It is a measure of the amount of alkali required to saponify a unit weight of fat, and is expressed as milligrams of potassium hydroxide required to saponify one gram of fat. The saponification value is equal to the acid for pure fatty acids (Pomeranz and Meloan, 1971).

Iodine number is a measure of the degree of unsaturation of a fat. Its determination is important both in classification of fats and oils and for control of manufacturing processes. The iodine values are less than 100 for nondrying oils, 130 to 200 for drying oils with semidrying oils having intermediate values. Theoretically, the iodine values for oleic, linoleic and linolenic are 89.9, 181.0 and 273.5, respectively (Pomeranz and Meloan, 1971).

The free fatty acid content of a fat, usually expressed as percent oleic acid, is a measure of the extent of hydrolysis of a fat. Combined with acid phosphates, and amino acids, it is called the fat acidity and is an index of deterioration of oilseeds (Zeleny and Coleman, 1938; Anderson and Alcock, 1954; Baker et al., 1959).

### Watermelon Seed Oil

Oke (1965) reported that Nigerian watermelon seed contained 31.9% crude protein, 57.1% ether extract, 8.2% crude fiber, 4.4% carbohydrates, and 6.2% ash, on a dry weight basis. The oil contained mostly palmitic, stearic, oleic and linoleic acids, with oleic and linoleic predominating. The oleic acid content ranged from 13.6% to 18.1% while the linoleic acid ranged from 52.3% to 57.9% (Girgis and Said, 1968; Oyenuga and Fetuga, 1975). Sudanese and American watermelon seed oil contained the same kinds of fatty acids as Nigerian watermelon seed oil, but had a much higher content of linoleic acid (62%) (Mustafa et al., 1972); Sao and Potts, 1952). Indian watermelon varieties contained about 47% oil in the kernel. The oil contained 8 classes of polar lipids, with phosphatidylcholine (lecithin) and phosphatidyl-inositol predominating. About 80 to 90% of the polar fraction consisted of phospholipids. Watermelon seed was reported to contain tannin and essential oils, but no alkaloids (Fefer et al., 1954). The fatty oils, as well as aqueous and alcohol extracts of the hull or kernel, paralyzed tapeworms and round worms in cats. This anthelmintic activity was higher than that of pumpkin seeds (Fefer et al., 1954).

# MATERIALS AND METHODS

Watermelons used in preliminary studies were purchased from the Alachua County area in June, 1976. Those used in the rest of the studies were donated by the Watermelon Growers Association at Lakeland, and processed at the Agricultural Research and Education Center at Lake Alfred, Florida, in July 1977. Pineapple and grapefruit concentrates were provided by the Ben Hill Griffin, Inc., Frostproof, Florida, under the brand name of Golden Nip. Orange juice concentrate was donated by the Birds Eye Division of General Foods, Winter Haven, Florida.

## Preliminary Studies

Investigations were conducted on the gross composition of watermelon, proximate analysis of watermelon parts and the juice quality.

### Gross Composition

Three mature 'Charleston Gray' melons weighing from 8 to 12 kg each were randomly selected, washed, wiped clean with paper towels, cut longitudinally into 6 or 8 wedges, and separated into rind and flesh. The flesh was then juiced in a juicing machine (Reeves Pulley Co., Columbus, Ind.) equipped with a 6mm-screen finisher. The pulp and seeds were placed in a basket centrifuge. Intermittent washing with a water spray during centrifugation ensured the separation of clean seeds, which were then blotted dry with paper towels. The rind, flesh, juice and seeds were weighed, and expressed as relative percentage, pulp or rag being calculated by difference.

## Proximate Analysis

The rind, flesh and seeds were analyzed for moisture content by drying in a freeze dryer for 32 hours, with a shelf heat of 55°C and under a pressure of 100 microns. Dried materials were then ground with a mortar and pestle. A small fraction of each was redried in a vacuum oven overnight, and placed in a desiccator. Each fraction was then placed in a Whatman cellulose thimble, and extracted with petroleum ether (b.p. 40 to 60°C) in a Goldfish apparatus for 16 hours. The extract, after evaporation of the solvent, was dried in a 100°C oven for 15 minutes, cooled in a dessicator and weighed. Fat-free materials were analyzed for protein by the micro-Kjeldahl method (AOAC, 1970). The factor used for converting nitrogen to protein was 6.25. Three to 5 grams of dried samples were ashed in previously ignited, cooled and weighed crucibles in a muffle furnace at 600°C for 18 hours. Samples were than removed, cooled in a desiccator and weighed. Total carbohydrate was calculated by difference. All calculations were made on a dry weight basis, then converted to fresh weight basis by multiplying with a factor equivalent to the ratio of dry weight to fresh weight.

## Juice Quality

Major factors determining the juice quality were percent total soluble solids (°Brix), pH, titratable acidity, vitamin C content, color, and mineral content.

### Brix

Readings for Brix were made with an Abbe' refractometer with temperature correction to 20°C.

### Titratable acidity (TA) and pH

The pH was determined potentiometrically. Titrations to determine TA were carried out to pH 8.3, using 0.1 N standard sodium hydroxide and a pH-meter.

### Ascorbic acid content

Determinations were made by titration method adapted from the National Canners Association (Townsend et al. 1956).

### Color

Measurements were made with a Gardner Automatic Color Difference Meter Model AC-1, using standard red tomato tile ($L=24.5$; $+ a_L=27.6$; $+ b_L=13.2$). Juice samples were placed in Agtron cells, introduced in the illumination area of the meter and covered with a white cardboard paper. The illuminated area was made smaller than the instrument detector's viewing area to avoid any trapped light, and consequently to avoid inaccurate measurement. The white backing was used to prevent any color loss by transmitted light. These two precautionary measures are necessary in color measurement of transluscent bodies such as watermelon and citrus juices.

### Mineral content

Determinations were made by the Analytical Research Laboratory of the Soils Department at the University of Florida.

Sample preparation and methods of analysis were as follows. Two-hundred milligrams of the prepared ash weighed to the nearest 0.1 mg were dissolved in several sequential aliquots of 2 N HCl, making a total of 5 ml. Each aliquot was diluted with deionized distilled water and filtered through Whatman no. 1 filter paper into a 50 ml volumetric flask, which was brought up to volume with additional deionized distilled water. Each sample was then transferred to a 100 ml screw-capped glass milk dilution bottle, and sent to the Soils Laboratory.

Calcium, cobalt, copper, chromium, iron, magnesium, manganese, nickle, strontium and zinc were determined by the use of a Perkin-Elmer Atomic Absorption Sepctrophotometer, Model 303 (Perkin-Elmer Corp., Norwalk, CT). Potassium and sodium were determined with a Beckman B Flame Emission Spectrophotometer (Beckman Inst. Fullerton, CA). Phosphorus was analyzed colorimetrically by a Coleman, Model 54, Digital Spectrophotometer (Perkin-Elmer Corp., Norwalk, CT). Results were reported as milligrams of mineral per 100 g of fresh sample.

## Watermelon Concentrate

Six hundred 'Charleston Gray' melons each weighing 8 to 12 kg were used in the preparation of watermelon concentrate.

### Concentration Methods

Methods used to concentrate watermelon juice were freeze concentration, low pressure concentration (vacuum evaporation) and thermally accelerated short time evaporation (TASTE). Equipment used for the first 2 methods were located in the Department of Food Science and Human Nutrition of the University of Florida at Gainesville. The TASTE evaporator, belonging to the Florida Citrus Commission, was located at the Agricultural Research and Educational Center (AREC) at Lake Alfred, Florida. Experiments were carried out as follows.

Freeze concentration

The juice was placed in 5-gallon plastic buckets and stored at -6°F. The frozen blocks were removed from the buckets by spraying water on the outsides of the buckets. The blocks were then split longitudinally and laterally into quarters. Each quarter of the block was then fed into an ice crusher to be reduced into small particles which were spun in a basket centrifuge for 2 min. to expel syrup (Fig. 3). The collected syrup, still containing much water at this stage, was refrozen, and subjected to the same process, with centrifugation for 1 min.

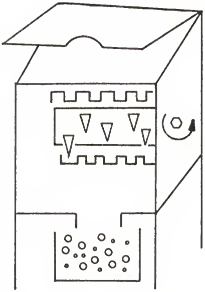
Low-pressure concentration

Operation consisted of placing the juice in the glass container A of the evaporator (Fig. 4) and subjecting it to a low pressure (49 mm Hg) and 18°C for about 6 hours to concentrate from 5 to 1 by volume. Volatiles could be trapped in container B and various traps installed between B and the vacuum pump.

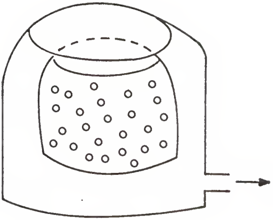
TASTE

This evaporator (Fig. 5) was a pilot plant with 4 stages, 3 effects and a capacity of removing 227 kg of water per hour as compared to the modern commercial evaporator having 7 stages, 4 effects, and 18,100 kg/hr. capacity. It was fully automated, and could concentrate the juice to 65° Brix in 3 minutes, during which time the juice stayed at 99°C for 6 seconds, thus providing effective pasteurization of the

Fig. 3 - Diagram of the ice crusher (A) and basket centrifuge (B) used in freeze concentration



(A)



(B)

Fig. 4 - Diagram of the low-pressure concentration. (A) Evaporating flask; (B) Condensate collector; (C) Steam heat exchanger; (D) Thermometer; (E) Pressure gauge; (F) Ice-cooled condenser; (G) Juice feed, and concentrate output

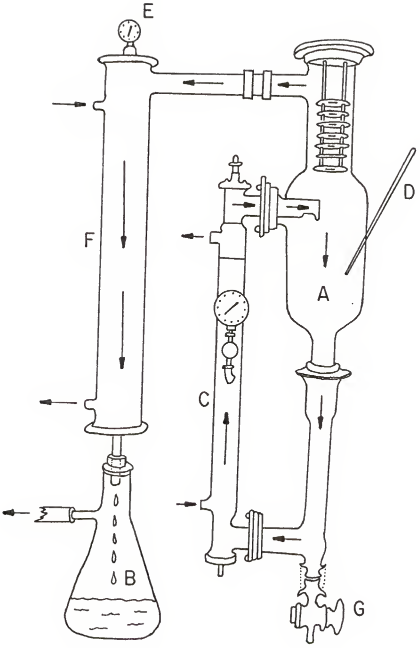
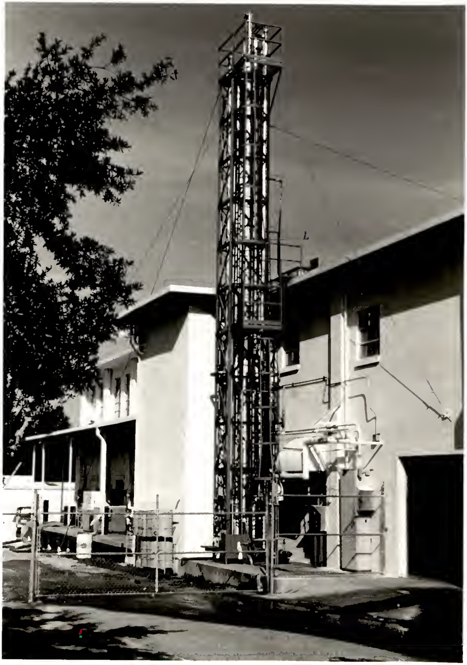

E
D
F
A
C
B
G

Fig. 5 - Photograph of the
thermally accelerated short
time evaporator (TASTE)



concentrate. A detailed operation of the evaporation may be obtained from the Gulf Machinery Co., Clearwater, Florida.

### Concentrate Quality

The concentrate obtained from the 3 methods were examined for total soluble solids ($^{o}$Brix), flavor and color. Brix was determined with an Abbe' refractometer. Flavor of reconstituted juice (9.8$^{o}$ Brix) was rated sensorially on a 9-point hedonic scale by 6 well-trained panelists. Color of reconstituted juice was objectively evaluated from L, $a_L$, $b_L$ values with the Gardner Automatic Color Difference Meter and convertion of $a_L$ and $b_L$ into saturation index S.I. + $(a^2 + b^2)^{\frac{1}{2}}$ and hue angle $\theta = \cos^{-1} \frac{a}{c}$. The best color having a rating of 3, had the highest L value, a comparable hue angle to that of fresh juice and the highest saturation index. Moderate and poor colors were given a rating of 2 and 1, respectively.

### Concentrate Flow Behavior

The apparent viscosities of 65$^{o}$ Brix watermelon concentrate and three citrus concentrates(62$^{o}$ Brix orange juice, 66$^{o}$ Brix 'Honey' tangerine juice, 53$^{o}$ Brix grapefruit juice) were determined at 25$^{o}$C with the aid of a Brookfield RVT Model viscometer equipped with cylindrical spindles no. 1 for watermelon and 'Honey' tangerine and no. 2 for grapefruit and orange juice.

Each can of frozen concentrate was thawed at room temperature, opened, poured into a 600 ml beaker and held in a water bath until internal temperature reached 25$^{o}$C before measurements were made. Readings were taken every 30 seconds at 0.5, 1.0, 2.5, 5.0, 10.0, 20.0, 50.0 and 100 rpm. Data were converted to apparent viscosities at various shear rates with the aid of a computer program as described by Yoo (1972).

Flow behavior of 65° Brix watermelon concentrate at a constant shear rate was also studied. Spindle no. 1, and two constant speeds (10 and 100 rpm) were used. Readings were taken every 5 min. for 20 min., then every 10 min. for the next 20 min., and at 30 min. intervals until a cumulative total of 250 min. were reached. Results were expressed as dial readings.

### Major Pigment

Lycopene was extracted with a chloroform solvent system, and also with a hexane system, using samples of 10 ml and 25 g, respectively.

#### Chloroform system

Ten milliliters of watermelon concentrate were shaken with 50 ml of acetone in a 500 ml separatory funnel, 25 ml of chloroform were then added, and the mixture shaken again. Then 200 ml of water were added and the mixture swirled thoroughly before allowing the 2 immiscible solvents to separate. The chloroform layer was withdrawn and mixed with a small amount of sodium sulfate.

#### Hexane system

Twenty-five grams of concentrate were extracted with an acetone hexane mixture (75:60, v/v) according to the general procedure used for separation of tomato carotenes by Zscheile and Porter (1947), as modified by Tomes et al. (1963) in their analysis of carotene pigment of some red-fleshed watermelons. Xanthophylls and acidic materials were removed by shaking with 85% aqueous methanol.

Absorption spectra of lycopene extracts were scanned with a Beckman Model 25 Recording Spectrophotometer (Beckman Inst., Fullerton, CA) in the visible range, 400 to 700 nm.

## Utilization of Watermelon Concentrate

### Fruit Punch

### Bench-top tests

A bench-top evaluation, using 5 well-trained panelists, was conducted to explore the possibility of using watermelon (W) in combination with 2 or 3 following fruit juices: pineapple (P), orange (O) and grapefruit (G). Four combinations, WPO, WOG, WPG and WPGO, each containing equal amounts of fruit juices, were tested.

### Laboratory and small-scale consumer tests

#### Formulation

Watermelon, pineapple and orange juice concentrates were used as primary ingredients of a fruit punch. Amounts of juice in various punches were: 100%, 50%, 20%, 10%, each having 15:1 Brix:acid ratio, and 10% having 25:1 Brix:acid ratio.

The 100% juices were prepared by reconstituting all concentrates to 12.4° Brix, mixing them together in proper proportions as determined by the experimental design selected for this study, and adjusting the titratable acidity (TA) to 0.827 with citric acid, so that the Brix:acid ratio (B:A) was 15:1. The 50%, 20% and 10% juices were prepared similarly. They contained 2, 5, and 10 times less fruit sugar and acidity. Therefore, enough sugar and citric acid were added to raise the Brix and TA to 12.4 and 0.827 respectively. Brix was kept at 12.4, but TA was lowered to 0.496 for the 10%-25:1 juice.

#### Testing and analysis of the results

Both laboratory and small-scale consumer tests were carried out to evaluate overall acceptability of various juice combinations.

For laboratory tests, 10 treatments were compared within each category of juice in a balanced incomplete block design in which 5 treatments were presented to each panelist in a random manner, and rated on a 9-point hedonic scale. Randomness was ensured by placing the juice in coded cups on a round paper plate. Treatments were replicated 9 times over 18 blocks, represented in this case by panelists. Each pair of treatments was compared 4 times. This design fitted plan 11.17 ($t=10$, $k=5$, $r=9$, $b=18$, $\lambda=4$) of Cochran and Cox (1957). A balanced incomplete block design was used because it was not possible to present 10 cold drinks to a panelist in one sitting. The data were analyzed by the statistical analysis system SAS76 (Barr et al., 1976). Adjusted treatment means from the intrablock analysis were compared manually, using Duncan's New Multiple Range test.

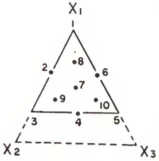
A mixture response surface model, using the Scheffe' second degree polynomial was used to fit the treatment means, predict the responses, and generate data for contour plotting (Scheffe', 1958; Snee, 1971; Cornell and Ott, 1975)

The 10 treatment combinations used (Table 1) were selected to cover the entire range of the triangular simplex over which the surface was represented. The fractional proportions of watermelon ($x_1$), pineapple ($x_2$), and orange ($x_3$) in each treatment must add up to 1.

The objective was to maximize watermelon utilization; hence a minimum of 30% (=0.30) watermelon was set for each treatment. Therefore, the maximum possible proportion of watermelon, pineapple and orange, that could be assigned to each treatment, were 100%(=1.00), 70%(=0.70) and 70%(=0.70),respectively.

Table 1. Treatment combinations

| TRT | Juice Proportions | | |
|---|---|---|---|
| | $x_1^w$ | $x_2^y$ | $x_3^z$ |
| 1 | 1.00 | 0.00 | 0.00 |
| 2 | 0.65 | 0.35 | 0.00 |
| 3 | 0.30 | 0.70 | 0.00 |
| 4 | 0.30 | 0.35 | 0.35 |
| 5 | 0.30 | 0.00 | 0.70 |
| 6 | 0.65 | 0.00 | 0.35 |
| 7 | 0.54 | 0.23 | 0.23 |
| 8 | 0.80 | 0.10 | 0.10 |
| 9 | 0.40 | 0.40 | 0.20 |
| 10 | 0.40 | 0.20 | 0.40 |



$^w$ $x_1$ = watermelon

$^y$ $x_2$ = pineapple

$^z$ $x_3$ = orange

To place the proportion of these 3 components on the same scale (0 to 1), a transformation of data was made, using the following formula:

$$x_1' = \frac{x_1 - 30}{70}$$

$$x_2' = \frac{x_2}{70}$$

$$x_3' = \frac{x_3}{70}$$

$x_1'$, $x_2'$ and $x_3'$, known as pseudo-components were used in the Scheffe' prediction model:

$$\hat{y} = b_1x_1' + b_2x_2' + b_3x_3' + b_1b_2x_1'x_2' + b_1b_3x_1'x_3' + b_2b_3x_2'x_3'.$$

Samples were placed in lidded plastic cups for small-scale consumer tests. Coded cups were transported to testing areas in styrofoam chests packed with ice. The 100% juice was tested in front of a supermarket. This involved authorization of both the Public Health Service and the manager of the store, which later became impossible to obtain. The rest of the testing was carried out in front of Library West on Campus. At both places, each panelist was presented 2 samples and asked to say which one of the samples he/she preferred or if there was no preference. "Having no preference" was assumed to mean cannot tell the difference, and was explained to the panelist by the person presenting the samples.

Three categories of juices were tested; 100% and 50% with 15:1 ratio and 10% with 25:1 ratio. Three treatments were compared within a paired-comparison test according to the method of Rao and Kupper (1967). Each treatment was replicated 60 times. Data were analyzed with a computer terminal, using APL language.

The best treatments, one from each of the 3 categories of juices, were compared in a final small-scale consumer test, using the same procedure as before.

### Grapefruit-Watermelon Mixtures

### Flavor enhancement of white grapefruit juice with watermelon concentrate

White grapefruit juice concentrate was reconstituted into 3 categories of juices having 7, 9 and $11^{\circ}$ Brix. The $7^{\circ}$ Brix juice received 0, 4, 6 and 8 ml of $60^{\circ}$ Brix watermelon concentrate. The 9 and $11^{\circ}$ Brix juices received each, 0, 1, 2 and 3 ml of $60^{\circ}$ Brix watermelon concentrate.

Each category of juice was tested separately, and repeated 3 times. Each treatment had 13 replications. All treatments within each category of juice were compared for flavor, in a multiple comparison test by a sensory panel using a 9-point hedonic scale. Juices were chilled to $5 \pm 1^{\circ}C$, and poured into coded small plastic cups just prior to sensory evaluation. The cups were placed on a round paper plate to ensure random order of sample presentation.

### Color enhancement of white grapefruit juice with watermelon concentrate

Small amounts of $60^{\circ}$ Brix-watermelon concentrate were added to several plastic bottles each containing 100 ml of white grapefruit juice reconstituted to $10^{\circ}$ Brix from frozen concentrate. The mixture was shaken and let stand to warm up to room temperature. It was then shaken again and poured into test-tube cells to compare with visual color standards in use at AREC, Lake Alfred. The visual scores of these standards ranged from 1 to 11, with a score of 1 being greenish yellow, and 11, good pink color.

Objective measurements were also made, using a Hunter Color Difference Meter D25 D2P with integrating sphere collector (Hunter Associates Lab., Fairfax, VA), total transmission mode, and a cell path length of 1 cm. Hunter $a_L$ and $b_L$ values were converted to S.I. and $\theta$ as described earlier.

Color stability and storage study of grapefruit-watermelon mixture

Three types of juices were chosen for this study: 1) reconstituted juice, 2) frozen concentrate, and 3) pasteurized reconstituted juice. All measurements and calculations of S.I. and $\theta$ were made, using the Hunter meter and system, as previously described.

Reconstituted juice. Frozen concentrated grapefruit juice (FCG) was reconstituted to $10^o$ Brix. About 1.5% by volume of $65^o$ Brix watermelon concentrate was added. The mixture was shaken, and divided into 3 equal parts in capped 1-liter glass bottles, and stored at $4.4^oC$.

Measurements were made at 3-day intervals for 15 days, on an aliquot from the glass bottles. Time was considered the independent variable.

Frozen concentrates. The FCG was diluted to $40^o$ Brix with water, then about 4% by volume of $65^o$ Brix watermelon concentrate was added. The mixture was then weighed into 125 ml Erlenmeyer flasks to ensure that an equivalent amount of 25 ml of concentrated mixture was placed in each flask. The flasks were then stoppered and stored at -18, 2 and $10^oC$.

Measurements were made once a month for 3 months on samples diluted with 75 ml of water. The experimental design was a 3 x 4 factorial with temperature and time as the 2 factors. The levels were -18, 2 and $10^oC$ for factor temperature and 0, 1, and 3 months for factor time.

Pasteurized reconstituted juice. The reconstituted G:W mixture was pasteurized in a plate-type heat exchanger at 88°C for 7 seconds and filled at 85°C into 237 ml tin cans and 178 ml enamel cans, which were then steam exhausted, sealed, inverted for 2 minutes, cooled in a spray of tap water and stored at 0 and 27°C. Triplicate measurements were made once a week for 6 weeks. The experimental design was a 2 x 2 x 7 factorial with can, temperature and time as the 3 factors. The levels were tin and enamel for factor can, 0 and 27°C for factor temperature, and 0, 1, 2, 3, 4, 5 and 6 weeks for factor time.

## Watermelon Seed Protein Studies

### Protein Extraction

Frozen seeds were thawed out, washed thoroughly with high pressure water, dried overnight at 35°C in an air-draft oven, ground coarsely in a coffee grinder, sieved to remove larger hull particles, ground in a mortar and pestle and sieved again to remove most hull particles.

Proteins were extracted using an alkaline aqueous system suggested by Rhee et al. (1972) and adapted by Ahmed and Schmidt (1979), with the following modifications: (a) pH was adjusted to 10 with 6 N NaOH; (b) pH of the protein fraction obtained after centrifugation in a Westfalia Continuous Centrifuge was adjusted to 3.5 with 6 N HCl to precipitate the protein; (c) the precipitate was allowed to settle, and the liquid siphoned off; and (d) water was added, the pH readjusted to 3.5 and the mixture stirred for 1 hour before dialysis for 48 hours using tap water and eventual removal and freeze drying.

## Proximate Analysis of WPC and Kernel

Proximate analyses were carried out according to AOAC procedures (1970).

## Functional Properties of WPC

Four functional properties were studied: (1) solubility, (2) emulsifying capacity, (3) foaming capacity and (4) foaming stability.

### Solubility

The procedure used by Ahmed and Schmidt (1979) was adopted with the following modifications: (a) adjusted pH range was expanded to cover the minimum pH of 2 and the maximum of 12; (b) centrifugal force used to settle large sediments was 40,000 x G; (c) the supernatant, after being brought up to volume, was used to determine soluble proteins by the method of Lowry (1951); (d) the uncentrifuged samples, after receiving the same dilution as the supernatant, were used to determine total protein by Lowry procedure; (e) direct concentration readings from the Beckman Model 25 Spectrophotometer were used to determine protein concentrations in both soluble and total fractions and (f) the concentration readings were adjusted to zero with blank and 400 with a BSA standard having a concentration of 400 μg/ml.

### Emulsifying capacity

A modified procedure of Carpenter and Saffle (1964) was used. An amount of 1.25 g of WPC was blended with 50 ml of sodium phosphate buffer pH 7 in a 473 ml blending jar, with an Osterizer Cyclamatic Blender for 1 minute at 60 setting of Powerstat variable autotransformer. Then 150 ml of soybean oil were added through a small round opening at the bottom of the inverted blending jar, while blending at the same speed. Oil was added from a burette at a rate of 0.5 ml per second until the breaking point was reached. The emulsifying capacity was expressed as ml of oil emulsified by 1 g of protein (Kinsella, 1976).

### Foaming capacity and stability

The procedure used by Lawhon and Cater (1971) was applied in this study. Citrate-phosphate buffer was used to prepare 1% protein solution at pH 7.0. Fifty milliliter portions of the solution were pipetted and transferred to 2 stoppered 100 ml graduate cylinders. The cylinders were shaken horizontally for 1 minute at the rate of 2 cycles per second and were then placed upright. The total volume of liquid and foam after 30 seconds of standing was recorded as foaming capacity. Foaming stability was the average between volumes of the foam after 10 minutes and after 2 hours. Both values were expressed as ml per gram of protein.

## Amino Acid Profile of WPC and Kernel

Samples were hydrolyzed with 6N hydrochloric acid at 137°C, for 30 hours, using the procedure of Davies and Thomas (1973). Amino acids were quantitated by ion-exchange chromatography as described by Schwabe (1976) and Robbins (1978), using a 3-column Technicon Amino Acid Analyzer. The 0.6 cm I.D. x 120 cm-columns were packed with Technicon C-2 chromobead resin, 13 ± 0.5 μm. Technicon sulfate was used as the detection reagent. Technicon norleucine and amino acid solution (2.5 μm/ml) were used as internal and external standards, respectively. Areas under the peaks of the chromatograms were determined with a Technicon Integrator Calculator. Amounts of each amino acid were expressed as the percentage of total amino acid.

The amino acid (AA) scores, essential amino acid (EAA) indices, and chemical score (CS) were determined, using whole hen egg protein as reference, and calculated according to accepted methods as follows:

$$\text{AA score} = \frac{\text{mg AA in 1 g test protein}}{\text{mg AA in 1 g reference protein}} \times 100 \text{ (Pike and Brown, 1975)}$$

$$\text{EAA index} = \frac{\text{EAA content of test protein}}{\text{EAA content of reference protein}} \times 100 \text{ (Oser, 1965)}$$

$$\text{CS} = \frac{\text{per cent limiting amino acid}}{\text{per cent same amino acid in standard protein}} \times 100 \text{ (Robson et al., 1972)}$$

## Watermelon Seed Oil Studies

### Oil Content of Whole Seed and Kernel

Kernel oil content was analyzed, using the procedure of Bligh & Dyer, (1959) with the following modifications: (a) a 10 g sample of kernel was blended with 40 ml deionized water, 100 ml methanol and 50 ml chloroform in a Waring blender for 2 minutes; (b) 50 ml chloroform were added and the mixture blended again for 30 seconds; (c) 50 ml water were added; (d) after blending for 30 seconds, the mixture was filtered through Whatman no. 1 filter paper on a Coors no. 3 buchner funnel with slight suction provided by water aspiration; (e) the residue was reextracted with 100 ml chloroform, filtered into the same suction flask; (f) the residue was flattened; (g) the blender was rinsed with 25 ml of chloroform and the content poured into the buchner funnel to ensure complete extraction of the oil; (h) the combined extract was poured into a 500 ml-separatory funnel and shaken vigorously for 1 minute; (i) after 30 minutes, the bottom or chloroform layer was removed into a tared 500 ml flat-bottom flask to be evaporated to dryness in a rotary evaporator at $34^{o} \pm 1^{o}C$, and back-flushed with nitrogen before removal to dry completely under a slow stream of nitrogen for about 15 minutes.

Whole seed and kernel were analyzed, using the Goldfish apparatus as previously described. Amount of oil was expressed in both cases as percentage by weight of sample.

## Separation and Classification of Lipids

Weighed samples of oil between 0.8 and 1.0 g were placed on a 1 x 26 cm column packed with 7 g of 100/200 mesh Unisil silicic acid (Clarkson Chemical Co., Inc., Williamsport, PA) and eluted according to a modified procedure of Moerck and Ball (1973). A sequence of 600 ml of chloroform, 300 ml of acetone and 300 ml of methanol was used to elute neutral, glyco -and phospholipids, respectively. Fractions were tested for purity by spotting all on the same TLC plates, developed in a solvent system of petroleum ether, diethyl ether and acetic acid (70-30-2), and charred with 40% sulfuric acid. The TLC sorbent used was SilicAR TLC - 7 GF (MallincKrodt Chemical Works, St. Louis, MO). The quantity of each class of lipids was expressed as a relative percentage.

## Fatty Acid Composition of Neutral Lipid and Total Lipid

The lipid fractions were saponified, then esterified with 14% $BF_3$ - methanol (Applied Science Laboratories, Inc., State College, PA), using the procedures of Metcalf et al. (1966). Methyl esters were purified and separated by thin layer chromatography using the same procedure.

## GLC Analysis of Neutral Lipid

A Varian Aerograph Model 1520 gas chromatograph equipped with a Digital Integrator Model CSI 38 was used to analyze methyl esters of fatty acids. The 1.5 m x 4 mm ID glass column was packed with 100/120 mesh Gas-Chrom Q (Applied Science Lab., Inc., State College, PA), coated with 10% EGSS-X of the same source, and operated isothermally at 185°C. Flame ionization detector temperature was 240°C. The sample was dissolved in chloroform, and injected in fractions of 0.5 microliter at 240°C. Flow rates of gases were 40 ml, 40 ml and 400 ml per min. for He, $H_2$ and air, respectively. Peaks were identified by comparing relative retention times with those obtained from calibrated standard mixtures (Applied Science, Lab., Inc., State College, PA), using stearate as a reference. Relative percentages of fatty acids were calculated from peak areas obtained from the integrator.

## GLC Analysis of Total Lipid

A Hewlett Packard 7620A gas chromatograph equipped with an Auto Lab Sys. IV Electronic integrator was used. The 6' x 1/4" glass U tube column was packed with 100/120 mesh Gas-Chrom Q coated with 3% SP1000, and operated isothermally at 150°C. Flame ionization detector and injector temperatures were 270°C. The methyl esters were dissolved in hexane and injected in fractions of 1 microliter. The gas carrier was helium at a flow rate of 80 ml per min.

## Physical and Chemical Properties of Seed Oil

The properties evaluated were refractive index ($R^{40}$), specific gravity at 25/25°C, percentage unsaponifiable matter, saponification value (mg KOH/g sample), iodine value (cg iodine absorbed/g sample), peroxide value (meq of perioxde/1000 g sample), and free fatty acids (as % oleic). They were determined using accepted standard procedures (AOCS, 1976).

# RESULTS AND DISCUSSION

## Preliminary Studies

The 'Charleston Gray' cultivar was chosen for these studies because of its fair flesh color, high sugar content and ready availability. It represents about 60% of the total watermelon crop produced in Florida.

### Gross Composition

The flesh represented about 44% by weight of the whole fruit. It could be divided into juice, pulp and seeds, representing 40%, 3% and 1%, respectively (Table 2).

The amount of seeds, 1% by weight, may appear too little to recover. However, seed recovery would be attractive if large quantities of watermelon were processed, since it may provide a rich source of good quality protein and oil, and many other uses. In Asia, there are watermelon varieties that are grown exclusively for seeds, the rest being discarded as waste. These seeds are produced for human consumption. A good quantity is exported to other countries, including the United States. In Texas, certain cultivars could yield up to 4 times as much seed by weight per acre as soybean (Sao and Potts, 1952).

### Proximate Analysis

The rind contained higher amounts of moisture than the flesh (Table 3). Amounts of fat, protein and ash were similar for the rind and the flesh. Seeds contained about half as much moisture as the flesh, and the highest amounts of fat, protein and carbohydrates.

Table 2. Gross composition of 'Charleston Gray' watermelon

| Parts | Relative percentage (w/w) |
|---|---|
| Rind | 56 |
| Flesh | 44 |
| juice | 40 |
| pulp | 3 |
| seed | 1 |

Table 3. Proximate analysis of different parts of watermelon (% w/w fresh weight basis)

| | Moisture | Fat | Protein | Ash | CHO[y] |
|---|---|---|---|---|---|
| Rind | 93.2 | 0.1 | 1.1 | 0.9 | 4.8 |
| Flesh | 89.9 | 0.1 | 1.2 | 0.6 | 8.2 |
| Seed | 44.7 | 12.4 | 15.4 | 1.0 | 26.5 |

[y] Carbohydrate by difference

The use of the rind as a dry feed may not be economical in terms of energy required to remove the water. However, it could be used as a by-product after other main products, such as pectin or flavor extracts, have been removed. Otherwise, it would be more profitable to utilize it as sugar concentrates, pickles or candied peel. The latter could be an interesting product by itself or mixed with other candied fruits for the manufacture of certain bakery products.

Juice Quality

Average total soluble solids (TSS) content was $9.8^{o}$ Brix (Table 4), but could be as high as $11.4^{o}$ Brix depending on location, environment and cultural practices. These values were higher than some orange cultivars, particularly 'Hamlin' and 'Parson Brown'. Minimum maturity standards for TSS are 8.0 Brix for cannery oranges and even lower for cannery grapefruit, $6.5^{o}$ Brix. In terms of pounds of solids, watermelon could produce more and at a lower cost than either orange or grapefruit.

Juice acidity is low and comparable to that of fully ripe mangoes (Soule and Harding, 1956). Adjustment to a more acid product is needed to achieve a balanced flavor and to reduce thermal processing times in order to preserve the flavor. Mixing of watermelon juice with other fruit juices having high acidity such as plum or citrus juices is preferred over addition of organic acids such as citric, tartaric and ascorbic acid (Gusina et al., 1971).

Vitamin C content is low, although 1 kg slice would provide more than the recommended daily dietary allowance of 45 mg for a normal adult (Martin and Coolidge, 1978).

Table 4. Quality of 'Charleston Gray' watermelon juice

| | |
|---|---|
| Total soluble solids ($^{o}$Brix) | 9.8 |
| Titratable acidity (%) | 0.07 |
| pH | 5.7 |
| Ascorbic acid (mg/100 g) | 5.4 |
| Color: L | 21.0 |
| $+a_L$ | 21.0 |
| $+b_L$ | 10.5 |
| Minerals (mg/100 g) | |
| Mg | 7.1 |
| Ca | 2.9 |
| Na | 2.6 |
| K | 89.5 |
| P | 9.0 |
| Fe | 0.2 |

The juice is rather dark, as indicated by its relatively low L value, more red ($a_L$) than yellow ($b_L$), and contains a fair amount of potassium. Other minerals are low as compared to other fruit and vegetable juices, except sodium. However, sodium is still low as compared to the 3 mg / 100 g limit of dietetic tomato juice (Watt and Merrill, 1975). Therefore, watermelon juice could be recommended as a dietetic juice.

## Watermelon Concentrate

### Concentration Methods and Concentrate Quality

Different methods to concentrate watermelon juice were evaluated in terms of their efficiency and the quality of the concentrates they produced (Table 5).

Freeze concentration produced the lowest amount of total soluble solids, highest flavor and poorest color. A large portion of the colored pulp was entrapped in the ice particles resulting in the poor color of the concentrate. Much space and energy were required to freeze the juice, crush the frozen block and centrifuge the ice particles. Better systems could produce more concentrated products, but the problems remain the same: loss of TSS and color and high cost.

Low-pressure concentration produced moderate TSS content, lowest flavor and moderate color. Prolonged evaporation and possible microbial contamination could be the reasons for lower flavor and color scores. The TSS content could not be increased without extending the evaporation period, which is detrimental to flavor and color.

TASTE produced the highest TSS content, high flavor and best color.

Table 5. Quality of concentrate produced by different methods

| Method | °Brix | Flavor[y] | Color[z] |
|---|---|---|---|
| Freeze conc. | 28 | 8.0 | 1 |
| Low-pressure conc. (49mm Hg, 18°C) | 45 | 6.0 | 2 |
| TASTE | 65 | 7.2 | 3 |

[x] Thermally accelerated short time evaporation.

[y] Flavor rating on a 9-point hedonic scale: 1 = dislike extremely, 9 = like extremely

[z] Color rating scale: 1 = poor, 2 = moderate, 3 = best

Flavor and color were retained due to the high temperature-short time effect of the evaporation, which was effective in inhibiting enzyme and microbial activities. No essence recovery system was used with this method of concentration. However, recovery of the essence and its addition to the concentrate would result in additional improvement of concentrate produced by this method. Color quality seemed to increase with increasing temperature used in concentration. All color values increased as the temperature increased from freezing temperatures (freeze-concentration) to 99°C (TASTE) with those produced by the TASTE method approaching the color values exhibited by fresh juice (Table 6). Color of the juice reconstituted from a TASTE concentrate was closer to the color of Campbell standard processed tomato red color than reconstituted juices prepared from other concentrates.

A space representation of the color points produced by each concentration method is shown in Fig. 6. TASTE produced a concentrate, which upon reconstitution to single strength, had the highest saturation index, and was closest to fresh juice in color.

### Flow Behavior

Flow behavior of 65° Brix watermelon concentrate (WC) was studied in conjunction with 3 citrus concentrates having 53° to 66° Brix. Apparent viscosity of WC decreased from 20 to 2 poises as shear rate increased from 2 to 100 $sec.^{-1}$, indicating a pseudoplastic behavior (Fig. 7). This behavior was also demonstrated by the value of flow behavior index of WC (n=0.3514). Other concentrates exhibited similar behavior, except 'Honey' tangerine concentrate which showed a relatively constant apparent viscosity throughout the shear rate range of 2 to 100 $sec.^{-1}$. Flow-behavior indices were 0.211 for orange concentrate, 0.3886 for grapefruit

Table 6. Color quality of fresh juice and juice reconstituted from watermelon concentrates prepared by different methods

| | L | $+a_L$ | $+b_L$ | Hue angle | S.I. |
|---|---|---|---|---|---|
| 1. Fresh juice (9.8°Brix) | 18.5 | 19.0 | 10.0 | 27.8 | 21.5 |
| 2. Reconstituted juice (9.8° Brix) | | | | | |
| (1) Fr. conc. | 17.4 | 13.4 | 5.4 | 22.0 | 14.4 |
| (2) L. Pressure conc. | 18.0 | 16.9 | 6.6 | 21.0 | 18.1 |
| (3) TASTE | 21.9 | 20.3 | 9.3 | 24.6 | 22.3 |
| Standard tomato red | 24.5 | 27.6 | 13.2 | 25.6 | 30.6 |

Fig. 6 - Space representation of hue angle and saturation index of fresh and reconstituted juice prepared from watermelon. (F) Fresh juice; (T) TASTE; (LPC) Low-pressure concentration; (FC) Freeze concentration

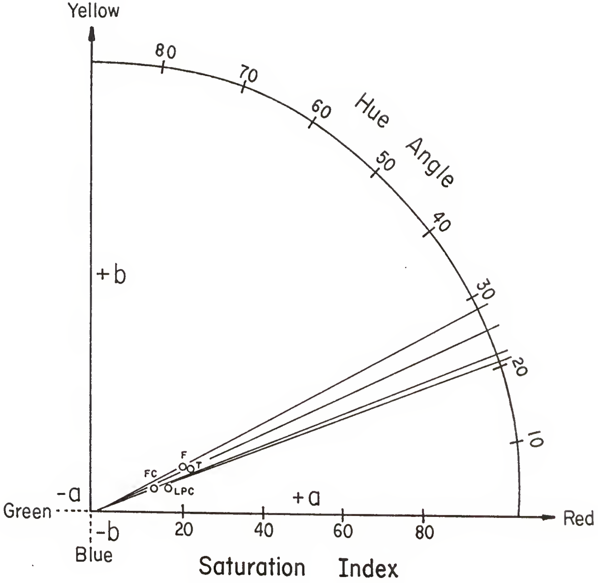
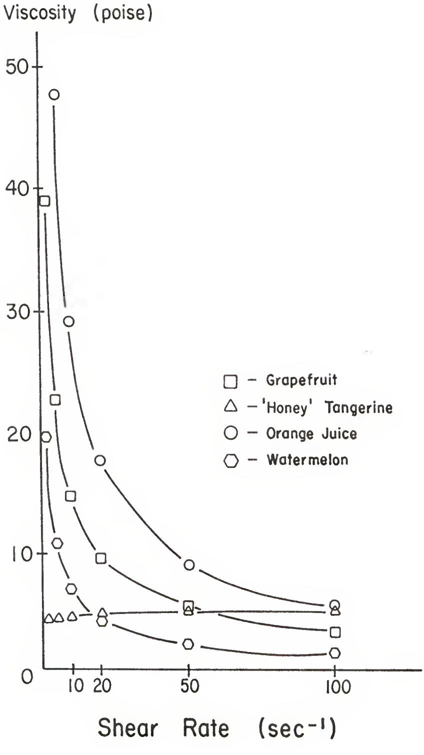

Yellow
80
70
60
50
40
30
20
10
Hue Angle
+b
F
T
FC
LPC
-a
+a
Green
-b
Blue
20
40
60
80
Red
Saturation Index

Fig. 7 - Flow behavior of watermelon (65° Brix), orange juice (62° Brix), 'Honey' tangerine (66° Brix) and grapefruit (53° Brix) concentrates


Viscosity (poise)
50
40
30
20
10
0
10
20
50
100
Shear Rate (sec⁻¹)
□ – Grapefruit
△ – 'Honey' Tangerine
○ – Orange Juice
⬡ – Watermelon

concentrate and 1.0597 for 'Honey' tangerine concentrate. The flow behavior index n is equal to the slope of the regression line obtained with the logarithmic plot of shear stress (dyne/cm$^{-2}$) vs. shear rate (sec.$^{-1}$). The value of n is equal to 1 for a Newtonian body, less than 1 for a pseudoplastic body and greater than 1 for a dilatant body under standard conditions.

Based upon the above observation, 'Honey' tangerine concentrate, having a relatively constant viscosity and a flow-behavior index of nearly equal to 1, can be considered as a Newtonian body. Apparent viscosities of WC were higher than those of 'Honey' tangerine at shear rates ranging from 2 to 18 sec.$^{-1}$ but the apparent viscosities of WC were lower than those of grapefruit and orange concentrates at all shear rates examined. Apparent viscosities of WC remained constant at constant shear rate over a period of time, indicating the flow behavior of WC is not time dependent. The lower apparent viscosity of WC (Fig. 7) would require less energy to pump and transport within a concentrate processing plant than orange or grapefruit concentrate. It also indicates that additional savings in power requirements in processing WC might be achieved by using shear rates higher than 20 sec.$^{-1}$.

### Major Pigment

Absorption spectra produced by chloroform and hexane extracts showed characteristic peaks. Absorption maxima occurred at 460, 485 and 518 nm for the chloroform extract (Fig. 8) and at 450, 477 and 508 nm for the hexane extract (Fig. 9). These values agree closely with those reported by Davies (1976). It is therefore possible to extract lycopene in a relatively pure form for possible use as a natural source of coloring

Fig. 8 - Absorption spectrum of a
chloroform extract of
watermelon lycopene

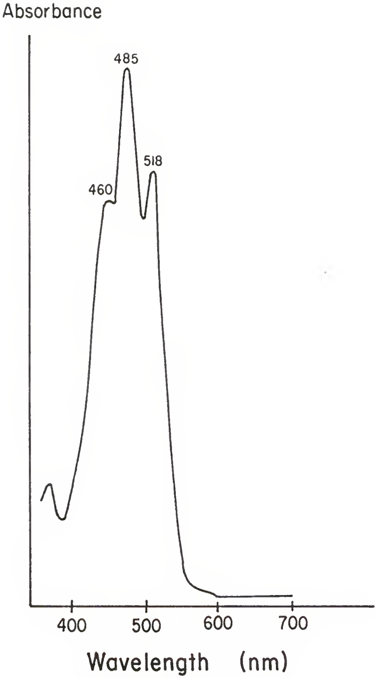
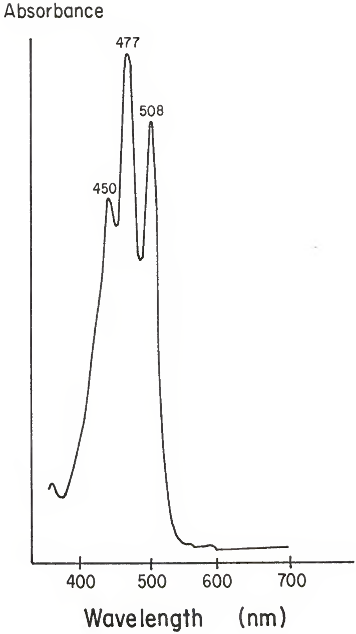

Absorbance
485
518
460
400
500
600
700
Wavelength (nm)

Fig. 9 - Absorption spectrum of a hexane extract of watermelon lycopene


Absorbance
477
508
450
400
500
600
700
Wavelength (nm)

matter for food or for other products in cosmetic or paint industries. However, the use of extracted lycopene as a food natural colorant will depend on the results of toxicological studies proving its safety for human consumption. There are the possibilities that changes in lycopene chemical structure or configuration might have occurred during the extraction process or an intermediate was formed due to the interaction of the organic solvent with the lycopene molecule or due to the incomplete removal of the organic solvents.

## Utilization of Watermelon Concentrate

### Fruit Punch

#### Bench-top test

Reconstituted juices from various fruit concentrates were mixed with different proportions of each fruit juice, then mixtures were evaluated sensorially by a bench-top type panel on the basis of acceptability, which was the combined sensation of flavor, color and consistency. Fruit punches containing watermelon, pineapple and orange fruit juices were the most acceptable among all combinations tested.

#### Laboratory tests

Observed means of acceptability scores assigned to each of the 10 treatments within each of the 5 types of juices tested are shown in Table 7. Treatment 1 of all juice concentrations containing 100% watermelon (W) received the lowest scores. These scores were significantly lower (0.05 level) than those given to treatment 5, containing 30% watermelon (W) and 70% orange (O), of all juice concentrations, except the 10% juice with 15:1 B:A ratio. They were also lower than those given

Table 7. Mean acceptability scores of fruit punch as influenced by composition and percentage of juice in the punch

| Treatment No. | Proportion$^z$ | | | Juice concentration (%) | | | | |
|---|---|---|---|---|---|---|---|---|
| | $x_1$ | $x_2$ | $x_3$ | 100 | 50 | 20 | 10 | 10 |
| | | | | 15:1 | | | | 25:1 |
| 1 | 1.00 | 0.00 | 0.00 | 5.47 | 5.27 | 5.28 | 5.18 | 4.60 |
| 2 | 0.65 | 0.35 | 0.00 | 5.79 | 6.34 | 6.23 | 5.80 | 6.05 |
| 3 | 0.30 | 0.70 | 0.00 | 6.12 | 6.74 | 5.83 | 6.58 | 6.28 |
| 4 | 0.30 | 0.35 | 0.35 | 7.17$^a$ | 6.94$^a$ | 6.03 | 5.65 | 6.18 |
| 5 | 0.30 | 0.00 | 0.70 | 7.24$^a$ | 6.92$^a$ | 7.23$^a$ | 6.73 | 7.05$^a$ |
| 6 | 0.65 | 0.00 | 0.35 | 6.67 | 6.64 | 6.30 | 6.48 | 6.18 |
| 7 | 0.54 | 0.23 | 0.23 | 6.69 | 6.49 | 5.93 | 6.95$^a$ | 6.08 |
| 8 | 0.80 | 0.10 | 0.10 | 6.19 | 5.99 | 6.25 | 7.03$^a$ | 5.93 |
| 9 | 0.40 | 0.40 | 0.20 | 6.42 | 5.74 | 6.45 | 6.15 | 5.43 |
| 10 | 0.40 | 0.20 | 0.40 | 6.67 | 6.59 | 6.25 | 6.23 | 6.00 |

[z] $x_1$ = watermelon, $x_2$ = pineapple, $x_3$ = orange

[a] Means significantly different from those of treatment number 1 within each juice concentrate at the 0.05 level. Each mean is an average of 3 replicates.

to treatment 4 (30% W:35% P:35% O) of 100% and 50% juices with 15:1 B:A ratios. Again they were lower than those given to treatment 7 (54% W:23% P:23% O) and treatment 8 (80% W:10% P:10% O) of 10% juice with 15:1 B:A ratio. However, they were not significantly different from the scores given to the rest of the treatments.

Highest scores were received by the treatment 8, containing 80% watermelon, 10% pineapple and 10% orange within the 10% juice with 15:1 B:A ratio group. It seemed to possess a sweeter taste provided by the watermelon, with some balance of sourness from the other components. This formulation appealed to the laboratory panel even though its juice concentration was low (10%). This observation was supported by the highest scores received by treatment 5 within the 10% (25:1) juice group, whose B:A had to be increased to be as well accepted as 100, 50 and 20% juices.

Treatment 1, which contained only watermelon juice was less acceptable than any other treatment containing pineapple and/or orange juice in addition to watermelon juice. This could be due to the fact that citric acid used to adjust the B:A ratios did not impart the appropriate sour taste to watermelon juice. Gusina et al. (1971) recommended addition of products having high natural acidity, such as plum purée for satisfactory processing and acceptability.

Based on these combinations, any type of juice, be it 10% or 100%, can be as well accepted as another, provided the formulation (proportion of juices used, and amount of sugar and acid added) is appropriate.

Juices with a B:A ratio greater than 15:1 are required for 10% juices, while those containing more than 80% watermelon are not recommended.

The response to other possible treatment combinations were predicted by Scheffe' quadratic and linear models. Parameter estimates and their goodness of fit for each type of juice are given in Table 8. Contour plots (Figs. 10-14) were constructed with predicted responses from both quadratic and linear models. They are in this case superimposed for purpose of comparison.

Contours given by the quadratic or complete model (Q) were almost linear for 100% juice with 15:1 B:A ratio (Fig. 10). This was expected because the coefficients of cross-product terms were very small. This means there was very little interaction, between watermelon and pineapple, watermelon and orange and pineapple and orange. If a cubic model were given, one would also observe that the coefficient of the ternary product is also small and so is the interaction among the 3 juices. The Q model contours in this case almost coincided with the linear or reduced model (L) contours and can be replaced by it. Coefficients of determination ($R^2$) of the Q and L models are 0.93 and 0.87, respectively (Table 8). The general increase in responses converges toward orange, with maximum at 70% orange and 30% watermelon. The lowest response is at $x_1' = 100\%$ watermelon.

The Q model contours provide more detail for other juice concentrations (Fig. 11-14). For example, the Q model contours showed a median surface, which slopes up or down toward a certain direction instead

Table 8. Parameter estimates and $R^2$ values for quadratic (Q) and linear (L) models

| Juice type | Model | $X_1'$ | $X_2'$ | $X_3'$ | $X_1'X_2'$ | $X_1'X_3'$ | $X_2'X_3'$ | $R^2$ |
|---|---|---|---|---|---|---|---|---|
| | | Parameter estimates | | | | | | |
| 15:1 | | | | | | | | |
| 100% | Q | 5.55 | 6.11 | 7.20 | -0.02 | 1.24 | 1.20 | 0.93 |
| | L | 5.55 | 6.23 | 7.45 | | | | 0.87 |
| 50% | Q | 5.35 | 6.67 | 7.00 | 0.56 | 1.57 | -1.35 | 0.70 |
| | L | 5.57 | 6.55 | 6.98 | | | | 0.61 |
| 20% | Q | 5.38 | 5.88 | 7.18 | 2.69 | 0.06 | -1.85 | 0.84 |
| | L | 5.67 | 5.91 | 6.95 | | | | 0.59 |
| 10% | Q | 5.39 | 6.45 | 6.59 | 1.59 | 4.00 | -2.73 | 0.52 |
| | L | 5.96 | 6.24 | 6.63 | | | | 0.10 |
| 25:1 | | | | | | | | |
| 10% | Q | 4.73 | 6.28 | 7.01 | 1.95 | 2.10 | -2.02 | 0.96 |
| | L | 5.20 | 6.24 | 6.99 | | | | 0.79 |

Fig. 10 - Quadratic (dashed lines) and linear (solid lines) model contours for 100% juice.

$$Q = \hat{y} = 5.55x_1' + 6.11x_2' + 7.2x_3' - 0.02x_1'x_2' + 1.24x_1'x_3' + 1.20x_2'x_3'$$

$$L = \hat{y} = 5.65x_1' + 6.23x_2' + 7.45x_3'$$

$\hat{Y}$ = predicted sensory response

$x_1'$ = pseudowatermelon component

$x_2'$ = pseudopineapple component

$x_3'$ = pseudoorange component

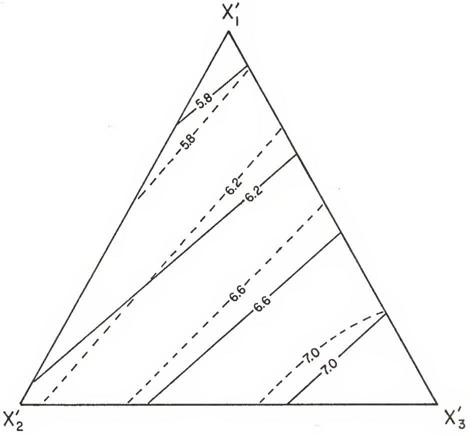

$X_1'$
5.8
5.8
6.2
6.2
6.6
6.6
7.0
7.0
$X_2'$
$X_3'$

Fig. 11 - Quadratic (dashed lines) and linear (solid lines) model contours for 50% juice.

$$Q = \hat{y} = 5.35x_1' + 6.67x_2' + 7.0x_3' + 0.56x_1'x_2' + 1.57x_1'x_3' - 1.35x_2'x_3'$$

$$L = \hat{y} = 5.57x_1' + 6.35x_2' + 6.98x_3'$$

$\hat{Y}$ = predicted sensory response

$x_1'$ = pseudowatermelon component

$x_2'$ = pseudopineapple component

$x_3'$ = pseudoorange component

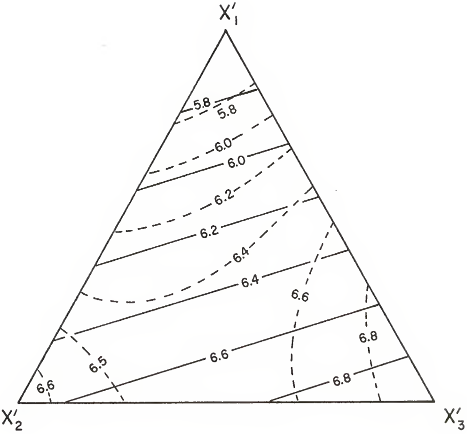

X'_1
X'_2
X'_3
5.8
5.8
6.0
6.0
6.2
6.2
6.4
6.4
6.6
6.5
6.6
6.6
6.8
6.8

Fig. 12 - Quadratic (dashed lines) and linear (solid lines) model contours for 20% juice.

$Q = \hat{y} = 5.38x_1' + 5.88x_2' + 7.18x_3' + 2.69x_1'x_2' + 0.06x_1'x_3' - 1.85x_2'x_3'$

$L = \hat{y} = 5.67x_1' + 5.91x_2' + 6.95x_3'$

$\hat{Y}$ = predicted sensory response

$x_1'$ = pseudowatermelon component

$x_2'$ = pseudopineapple component

$x_3'$ = pseudoorange component

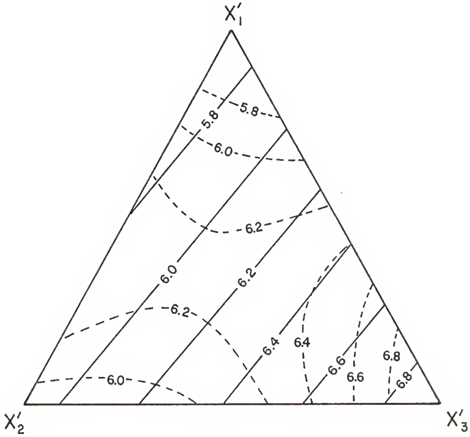

X'1
X'2
X'3
5.8
5.8
6.0
6.2
6.0
6.2
6.2
6.0
6.4
6.4
6.6
6.6
6.8
6.8

Fig. 13 - Quadratic (dashed lines) and linear (solid lines) model contours for 10% (15:1)juice

$Q = \hat{y} = 5.39x_1' + 6.45x_2' + 6.59x_3' + 1.59x_1'x_2' + 4.0x_1'x_3' - 2.73x_2'x_3'$

$L = \hat{y} = 5.96x_1' + 6.24x_2' + 6.63x_3'$

$\hat{Y}$ = predicted sensory response

$x_1'$ = pseudowatermelon component

$x_2'$ = pseudopineapple component

$x_3'$ = pseudoorange component

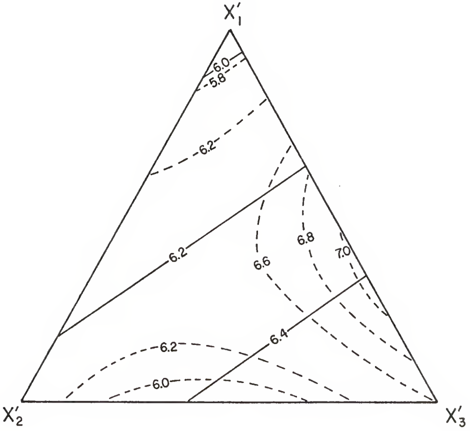

X'_1
X'_2
X'_3
6.0
5.8
6.2
6.2
6.6
6.8
7.0
6.4
6.2
6.0

Fig. 14 - Quadratic (dashed lines) and linear (solid lines) model contours for 10% (25:1) juice

$Q = \hat{y} = 4.73x_1' + 6.28x_2' + 7.01x_3' + 1.95x_1'x_2' + 2.10x_1'x_3' - 2.02x_2'x_3'$

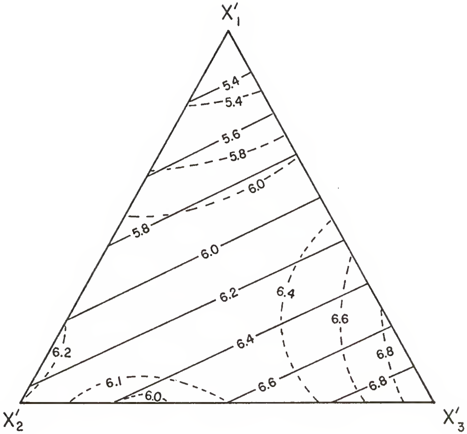
$L = \hat{y} = 5.20x_1' + 6.24x_2' + 6.99x_3'$

$\hat{Y}$ = predicted sensory response

$x_1'$ = pseudowatermelon component

$x_2'$ = pseudopineapple component

$x_3'$ = pseudoorange component


X'_1
X'_2
X'_3
5.4
5.4
5.6
5.8
6.0
5.8
6.0
6.2
6.4
6.6
6.4
6.6
6.8
6.8
6.2
6.1
6.0

of showing a smooth surface sloping up toward 70% orange, as in the case of L models. However, the L model contours can represent the Q model contours in all cases, considering the fact that the differences are small, except in 10% (15:1) juice, where the maximum response is not at 70% orange as indicated by L model contours but at some other place along the watermelon-orange axis ($x_1' - x_3'$). The coefficient of determination of the L model for this juice is only 0.1.

A model having the highest coefficient of determination should be used in formulation work, if a computer is available and if one is interested only in predicting the response from a set of factors. Such procedures as stepwise regression can be used for prediction.

Contour plots are very useful in fruit juice formulation because they show possible combinations producing the same response and thus provide alternatives to produce many products of equal acceptability. For example, the manufacturer would make a competitive product by using more of the cheaper ingredients and the most efficient conditions to manufacture a product of equal acceptability. Thus he would truly serve the consumers through both lower price and good-quality product if he could do it without sacrificing nutritional quality.

Small-scale consumer tests

Only 3 categories of juices were used, due to their popularity and the availability of resources. Three comparatively good treatments within each category of juices were tested.

Treatment C containing 40% watermelon, 30% pineapple and 30% orange for 100% juice, 15:1 ratio was most preferred (Table 9). Its probability

Table 9. Small-scale consumer tests with 100% (15:1) juice

A = 0.70 W:0.30 O
B = 0.40 W:0.60 O
C = 0.40 W:0.30 P:0.30 O

| Treatment pairs | Probability of preference A | B | C | Probability of no preference |
|---|---|---|---|---|
| AB | 0.44 | 0.40 | | 0.16 |
| AC** | 0.19 | | 0.70 | 0.11 |
| BC** | | 0.17 | 0.71 | 0.12 |

**Significant at 0.01 level

of preference was 70 to 71% over treatments A and B, which were not significantly different from each other, but were highly significantly different from C. In all cases, 11 to 16% of the consumers could not tell the difference between pairs of samples presented. Their senses of perception were not sharp enough to detect differences, due probably to the strong flavor notes of each component, tending to mask the dominant flavors, thus causing confusion among this group of judges. The differences among the sensing ability of the judges were taken into account in calculating the true rating of the treatments, because the objective of the study was to detect the difference among treatments.

The treatments A, B and C for 50% (15:1) juices, containing 0.30 W:0.70P, 0:30W:0.70 O, and 0.54W:0.23P:0.23 O, respectively, were not different (Table 10). The treatment combinations were rearranged in order to conform with model predictions and verify them with a larger and more reliable panel. The probability of no preference ranged from 2 to 3%. Fewer judges than in the case of 100% (15:1) juices could not tell the difference between pairs of samples. Flavor notes were probably more easily detected at lower juice concentrations. Treatment C containing up to 54% watermelon was not significantly different from the predicted best treatment B containing 70% orange.

The treatments A, B and C for 10%-25:1 juices, containing 0.65 W:0.35P, 0.65W:0.35 O, and 0.54W:0.23P:0.23 O, respectively, were not significantly different (Table 11). Treatment combinations

Table 10. Small-scale consumer tests with 50% (15:1) juice

A = 0.30 W:0.70 P
B = 0.30 W:0.70 O
C = 0.54 W:0.23 P:0.23 O

| Treatment pairs | Probability of preference A | B | C | Probability of no preference |
|---|---|---|---|---|
| AB | 0.49 | 0.48 | | 0.03 |
| AC | 0.50 | | 0.47 | 0.03 |
| BC | | 0.50 | 0.48 | 0.02 |

Table 11. Small-scale consumer tests with 10% (25:1) juice

A = 0.65 W:0.35P
B = 0.65 W:0.350
C = 0.54 W:0.23P:0.230

| Treatment pairs | Probability of preference A | B | C | Probability of no preference |
|---|---|---|---|---|
| AB | 0.43 | 0.50 | | 0.07 |
| AC | 0.39 | | 0.54 | 0.07 |
| BC | | 0.42 | 0.51 | 0.07 |

were rearranged for the same reason as in the case of 50% (15:1) juice and a few judges could not tell the difference between pairs of samples. Proportions of watermelon in treatment A and B were increased to 65% but no significant difference was detected.

The best treatment from 100% (15:1) juices and the treatments having the highest scores from 50% (15:1) and 10% (25:1) juices were compared in a final round (Table 12). No significant difference was found. As expected, a few judges could not tell the difference between pairs of samples because the categories of juices used were very different from each other.

It can be said as a general conclusion that the combination containing about one third each of watermelon, pineapple and orange is best for 100% juice. For other juice types, combinations containing up to 65 and even 80% watermelon of the juice mixture were well accepted. A 10% juice was as well accepted as a 50 or 100% juice, provided the formulation was appropriate. The difference is more easily detected at a lower juice concentration than at a higher juice concentration, thus a more careful dosage must be exercised while mixing fruit punches containing less fruit juice.

## Grapefruit-Watermelon Mixtures

### Flavor enhancement of white grapefruit juice with watermelon concentrate

Mean sensory flavor scores of white grapefruit juice (WGJ) to which were added various amount of $60^{o}$ Brix watermelon concentrate (WC) are shown in Table 13, where it may be seen that higher flavor scores were obtained as the amount of added WC increased. Larger amount of WC,

Table 12. Small-scale consumer tests with

A = 100% (15:1) juice = 0.40 W:0.30 P:0.30 O
B = 50% (15:1) juice = 0.54 W:0.23 P:0.23 O
C = 10% (25:1) juice = 0.54 W:0.23 P:0.23 O

| Treatment pairs | Probability of preference A | B | C | Probability of no preference |
|---|---|---|---|---|
| AB | 0.46 | 0.48 | | 0.06 |
| AC | 0.56 | | 0.38 | 0.06 |
| BC | | 0.57 | 0.37 | 0.06 |

Table 13. Flavor Enhancement of white grapefruit juice with watermelon concentrate

| Grapefruit[z] | | | Ml 60° Brix watermelon | | | |
|---|---|---|---|---|---|---|
| °Brix | T.A. | B:A | 0 | 4 | 6 | 8 |
| 7 | 0.75 | 9.3 | 5.3[y] | 5.6 | 6.4 | 6.0 |
| | | | 0 | 1 | 2 | 3 |
| 9 | 0.78 | 11.5 | 6.4 | 6.8 | 6.9 | 7.1 |
| 11 | 0.82 | 13.4 | 6.3 | 7.1 | 7.0 | 7.1 |

[y] Sensory flavor rating on a 9-point hedonic scale, where 1 = dislike extremely, 9 = like extremely.

[z] 100 ml

6.0 ml, was needed to effect a noticeable flavor improvement of WGJ with a B:A ratio of 9.3. The WGJ with B:A ratios exceeding 11.0 required a smaller amount of WC, 1.0 ml, to influence the flavor rating. This was primarily due to the initial total soluble solids content of WGJ. Higher initial values required smaller amounts of WC to result in an improvement in flavor rating.

### Color enhancement of white grapefruit juice with watermelon concentrate

The color of pigmented grapefruit segments and juice fades as the fruit advances in maturity and upon processing and storage of the juice. Watermelon concentrate could be added to white grapefruit juice to produce a juice blend having better flavor and color. Watermelon concentrate provides a natural source of color in a readily usable form. Its use in such a form does not necessitate the need for toxicological studies to prove its safety as in the case of color additives.

The addition of 1.0 and 1.5 ml of watermelon concentrate to 100 ml of white grapefruit juice resulted in a juice blend with a color having visual ranks between 6 and 7, hue angles between 76 and 81 and chroma around 20 (Table 14). This color is similar to that of the best commercial pink grapefruit juices (Huggart, 1978). These juices are still reddish yellow. Faintly pink juices having visual ranks between 2 and 3, hue angles between 90 and 97 and chroma around 19 should not be called pink. They are, according to their hue angle values, either yellow or greenish yellow. A better hue showing visibly pink coloration could be obtained by adding more $60^{\circ}$ Brix watermelon concentrate (up to 2.0 ml/ 100 ml grapefruit juice).

The relationship between chroma, hue angle and visual ranking could be best represented by the following diagram (Fig. 15). The hue angle

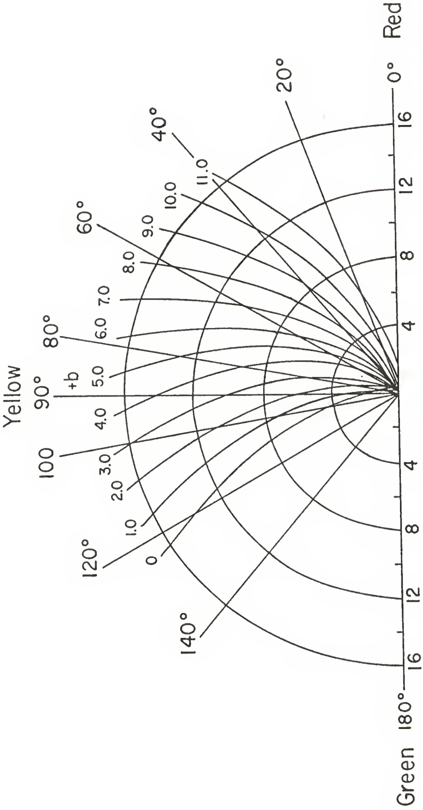
Table 14. Color enhancement of white grapefruit juice with watermelon concentrate

| Watermelon[y] (ml) | L | Chroma | Hue angle | Rank[z] |
|---|---|---|---|---|
| 0 | 56.2 | 19.1 | 96.9 | 2.0 |
| 0.5 | 52.3 | 19.7 | 87.1 | 4.5 |
| 1.0 | 49.9 | 20.2 | 81.2 | 6.0 |
| 1.5 | 47.6 | 20.7 | 76.0 | 7.0 |
| 2.0 | 45.5 | 21.5 | 70.7 | 10.0 |
| 9.0 | 29.6 | 28.0 | 40.5 | -- |

[y] 60° Brix watermelon added to 100 ml 10° Brix white grapefruit.

[z] Visual score standards of AREC Lake Alfred.

Fig. 15 - Chroma and hue angle vs. visual ranking of grapefruit juice. (From Huggart and Petrus, 1978)


Yellow
90°
+b
80°
100
60°
120°
40°
140°
20°
0° Red
180° Green
16
12
8
4
4
8
12
16
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0

decreases from about $120^{o}$ to $40^{o}$ as the visual rank increases from 0 to 11.0 and the chroma or saturation index (represented by half-circles) radiates out from 4 to 16. Optimum color of pink grapefruit juice possesses a visual ranking of 6.0 and 7.0 (Huggart, 1978).

Huggart et al. (1977) proposed a method to closely predict grapefruit juice visual color scores, using objective color measurements of hue angle and chroma. Objective methods have not been officially accepted by the State of Florida and the citrus industry. Thus, the method proposed by Huggart et al. (1977) could be an invaluable tool for assessing grapefruit juice color and may contribute to the success of frozen concentrated grapefruit juice, as has been the case with frozen concentrated orange juice. Use of an objective measurement under a standard light would overcome not only the bias of human eyes but also the object metamerism of grapefruit juice (Huggart et al., 1977); object metamerism is a condition in which the same object exhibits different colors under different light conditions.

### Color stability and storage study of grapefruit-watermelon mixtures

Reconstituted juice. Effects of storage duration at 4 ± $1^{o}$C on lightness (L), chroma (c) and hue angle ($\theta$) were highly significant (Table 15). Mean values for the 3 parameters were compared using Duncan's New Multiple Range test (Table 16). The dependence of L, c and $\theta$ on time is shown in Fig. 16-18.

All mean values, except few within the first 3 or 6 days of storage were statistically different. However, the differences were small. After 6 days of storage, the changes for L, c and $\theta$ were only 0.40, 0.16 and 0.65 unit, respectively, out of a possible 100. The reason for highly

Table 15. ANOVA of lightness (L), chroma (c) and hue angle (θ) of reconstituted grapefruit-watermelon mixture, as influenced by storage duration (Ti) at 4 ± 2°C

| Variable | Source | df | SS | MS | F | PR>F |
|---|---|---|---|---|---|---|
| L | Ti | 5 | 4.4561 | 0.8912 | 114.59 | 0.0001 |
| | Error | 12 | 0.0933 | 0.0078 | | |
| | Total | 17 | 4.5494 | | | |
| c | Ti | 5 | 2.2283 | 0.4457 | 93.73 | 0.0001 |
| | Error | 12 | 0.0570 | 0.0048 | | |
| | Total | 17 | 2.2853 | | | |
| θ | Ti | 5 | 20.4023 | 4.0804 | 437.63 | 0.0001 |
| | Error | 12 | 0.1119 | 0.0093 | | |
| | Total | 17 | 20.5142 | | | |

Table 16. Mean lightness (L) value, chroma (c) and hue angle (θ) of reconstituted grapefruit-watermelon mixtures, as influenced by storage duration at 4 ± 2°C

| Storage (days) | L | c | $\theta^o$ |
|---|---|---|---|
| 0 | 47.7 a[z] | 21.2 a | 73.5 a |
| 3 | 48.1 b | 21.2 ab | 74.0 b |
| 6 | 48.3 c | 21.4 b | 74.2 b |
| 9 | 48.7 d | 21.6 c | 74.8 c |
| 12 | 48.5 e | 21.8 d | 75.3 d |
| 15 | 49.3 f | 22.2 e | 76.8 e |

[z] Each mean is an average of 3 replicates.

Means within each column followed by the same letter are not significantly different at the 0.05 level.

Fig. 16 - Effect of storage duration over a 15-day period at 4 ± 2°C on lightness values of reconstituted grapefruit-watermelon mixture

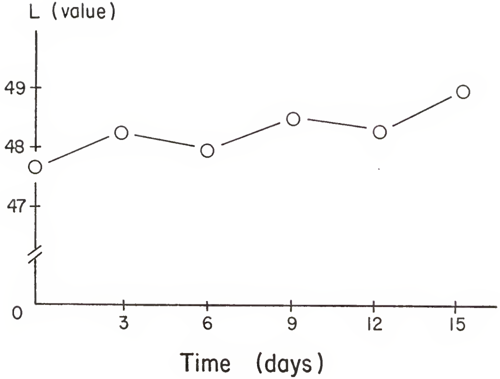

L (value)
49
48
47
0
3
6
9
12
15
Time (days)

Fig. 17 - Effect of storage duration over a 15-day period at 4 ± 2°C on saturation index (S.I.) of reconstituted grapefruit-watermelon mixture

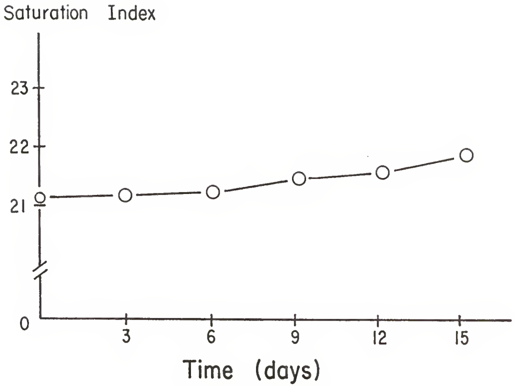
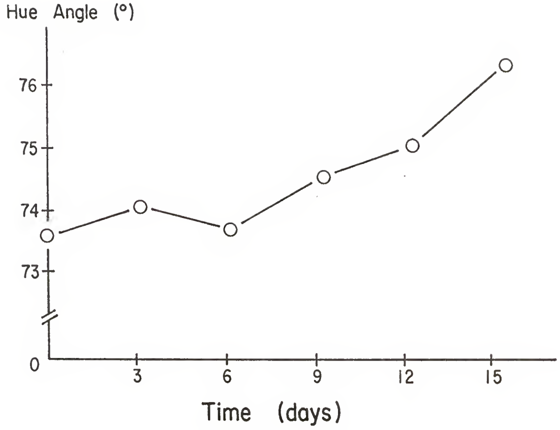

Saturation Index
23
22
21
0
3
6
9
12
15
Time (days)

Fig. 18 - Effect of storage duration over a 15-day period at 4 ± 2°C on hue angle of reconstituted grapefruit-watermelon mixture


Hue Angle (°)
76
75
74
73
0
3
6
9
12
15
Time (days)

significant differences was the small error variances used to compute the F-tests and compare the means. It can be said that for all practical purposes, the color of the G:W mixture is stable under normal home use conditions of reconstituted juice.

Juice color could be affected by microbial activities. Murdock and Hatcher (1975) reported the growth of yeast, leuconostoc and lactobacillus in chilled reconstituted orange juice stored at temperatures ranging from 1.7 to 10.0°C. Yeast grew at all temperatures investigated. Leuconostoc did not grow below 4°C, while lactobacillus did not grow below 10°C. The product is subject to microbial spoilage since it is not sterile. Murdock (1977) considered yeast and lactic acid bacteria as the predominant microflora and stressed the importance of low storage temperature and prevention of contamination. Accordingly, Carter (1978) recommended plants which reconstitute juice to pasteurize their product before packaging and distribution, the recommended time-temperature being one second at 85°C or 16 seconds at 74°C. This was primarily intended to kill microorganisms. Chilled juice made from fresh juice must have enzymes inactivated; so it requires a more severe thermal treatment, 91°C for 7 seconds.

Frozen concentrates. White grapefruit-watermelon frozen concentrates were stored at -18°C, 2°C and 10°C over a period of 3 months. Effects of storage temperatures, duration and their interactions on lightness (L) value, chroma (c) and hue angles ($\theta$) were highly significant (Table 17). The objective was to observe changes in color values over a period of time; hence mean effects of storage durations were compared within each storage temperature (Table 18), using Duncan's New Multiple Range test.

There were statistical differences but mean values of L, c and θ exhibited little change within each temperature tested and over the entire length of storage, except at the highest temperature used, 10°C, and during the third month of storage, where L, c and θ decreased abruptly. The product seemed to become redder when θ decreased from a value of 72.11 during the 2nd month to a value of 53.88 (Little, 1975; Huggart et al., 1977), although it still remained in the reddish yellow range. The product became dark brown instead, due to a large decrease in lightness value and a decreased in saturation index. A careful examination of the samples revealed mold growth. The strong fermented odor indicated an active spoilage by microbial agents, including possibly yeast. Murdock and Hatcher (1977) studied the survival of yeast in inoculated packs of frozen orange concentrate stored at temperatures ranging from 4.4°C to -17.8°C. They reported that yeast did not grow in 65° Brix concentrate at any temperature investigated over extended periods of storage but did grow in 45° Brix concentrate stored at 4.4°C after 2 months. Mold was noted in 45° Brix concentrate after 12 months of storage at -17.8° to -1.1°C but not noted in 65° Brix concentrate at all temperatures tested. Slight discoloration appeared in 45° Brix and 65° Brix concentrates after 7 and 15 months of storage at -1.1°C, respectively, but not at -9.4° and -17.8°C. Consequently, it can be said that 45° Brix white grapefruit-watermelon concentrate could be safey stored at 2°C or below for at least 3 months but not at 10°C for 2 months or less. It is expected that it will store well under commercial bulk storage tank

Table 17. ANOVA of lightness (L) value, chroma (c) and hue angle(θ) of grapefruit-watermelon frozen concentrates, as influenced by temperature (Te) and storage duration (Ti).

| Variable | Source | df | SS | MS | F | PR>F |
|---|---|---|---|---|---|---|
| L | Te | 2 | 162.0200 | 81.0100 | 95.71 | 0.0001 |
| | Ti | 3 | 206.9142 | 68.9731 | 81.49 | 0.0001 |
| | TexTi | 6 | 340.0200 | 56.6749 | 66.96 | 0.0001 |
| | Error | 24 | 20.3133 | 0.8464 | | |
| | Total | 35 | 729.2675 | | | |
| c | Te | 2 | 0.7177 | 0.3588 | 1.39 | 0.2686 |
| | Ti | 3 | 2.8502 | 0.9501 | 3.68 | 0.0260 |
| | TexTi | 6 | 1.9717 | 0.3286 | 1.27 | 0.3069 |
| | Error | 24 | 6.1992 | 0.2583 | | |
| | Total | 35 | 11.7389 | | | |
| θ | Te | 2 | 177.8308 | 88.9154 | 31.58 | 0.0001 |
| | Ti | 3 | 179.8589 | 59.9530 | 21.30 | 0.0001 |
| | TexTi | 6 | 525.3813 | 87.5636 | 31.10 | 0.0001 |
| | Error | 24 | 67.5682 | 2.8153 | | |
| | Total | 35 | 950.6392 | | | |

Table 18. Mean lightness (L) value, chroma (c) and hue angle (θ) of grapefruit-watermelon frozen concentrates, as influenced by temperature (Te) and storage duration (Ti).

| Te ($^{o}$c) | Ti (month) | L | c | θ$^{o}$ |
|---|---|---|---|---|
| -18 | 0 | 44.6 a[z] | 21.3 a | 71.1 a |
| | 1 | 44.6 a | 21.3 a | 71.0 a |
| | 2 | 45.2 b | 20.8 a | 72.4 b |
| | 3 | 44.9 b | 20.9 a | 73.4 b |
| 2 | 0 | 44.6 a | 21.3 a | 71.1 a |
| | 1 | 44.4 ab | 21.4 a | 71.4 a |
| | 2 | 44.7 a | 21.2 a | 71.6 a |
| | 3 | 43.4 b | 21.1 a | 71.8 a |
| 10 | 0 | 44.6 a | 21.3 a | 71.1 a |
| | 1 | 44.1 a | 21.4 a | 71.0 a |
| | 2 | 43.1 a | 21.0 ab | 72.1 a |
| | 3 | 28.5 b | 19.9 b | 53.9 b |

[z] Each mean is an average of 3 replicates.

Means within the same group containing the same letter are not significantly different at 0.05 level.

Fig. 19 - Effect of temperature (Te) and length of storage (Ti) on L value of grapefruit-watermelon mixture

$Te_1$ = -18°C

$Te_2$ = 2°C

$Te_3$ = 10°C

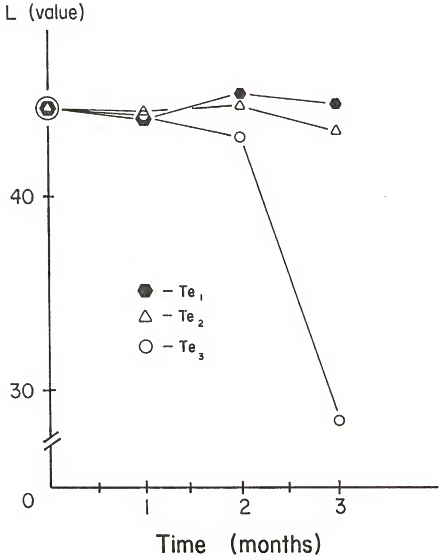

L (value)
40
30
0
1
2
3
Time (months)
⬣ – Te$_1$
△ – Te$_2$
○ – Te$_3$

Fig. 20 - Effect of temperature (Te) and length of storage (Ti) on saturation index of grapefruit-watermelon mixture

$Te_1 = -18^{\circ}C$

$Te_2 = 2^{\circ}C$

$Te_3 = 10^{\circ}C$

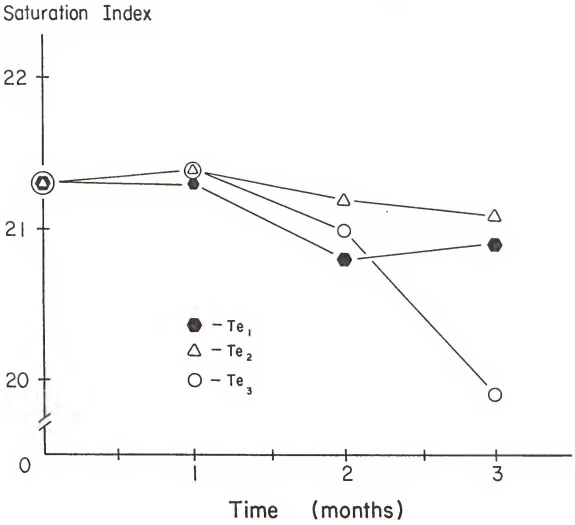
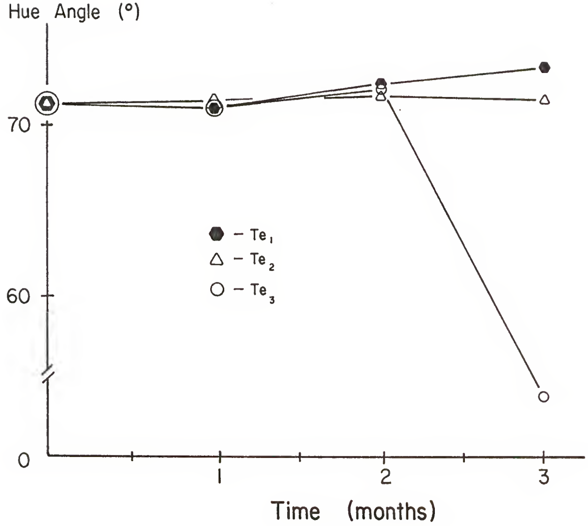

Saturation Index
22
21
20
0
1
2
3
Time (months)
● – Te₁
△ – Te₂
○ – Te₃

Fig. 21 - Effect of temperature (Te) and length of storage (Ti) on hue angle of grapefruit-watermelon mixture

$Te_1 = -18^oC$

$Te_2 = 2^oC$

$Te_3 = 10^oC$


Hue Angle (°)
70
60
0
1
2
3
Time (months)
● – $Te_1$
△ – $Te_2$
○ – $Te_3$

conditions where the storage temperatures reach -17.8$^{o}$C or below for 6 months without danger of microbial spoilage or discoloration. Effects of temperature and length of storage on L value, S.I. and $\theta$ of white grapefruit-watermelon frozen concentrates are illustrated in Figs. 19-21.

Pasteurized reconstituted juice. Most of the interactions among can type (C), temperature of storage (T) and length of time of storage (Ti) for L, c and $\theta$, were highly significant (Table 19). Effects of all factors and many interactions were highly significant, due to the small error variance used to compute the F-test. Means of C x T interactions as a function of Ti show very small differences (Table 20).

The largest change was produced by enamel can ($C_2$) and high temperature ($T_2$). This interaction, $C_2T_2$, resulted in a reconstituted juice mixture with reduced L value (Fig. 22), increased saturation index (Fig. 23) and reduced hue angle (Fig. 24), thus, producing a darker and deeper red color. The darkening was probably due to non-enzymic browning and/or the effect of enamel coating coupled with high storage temperature on white grapefruit juice. Commercially, this product is stored in tin cans, with the tin having a reducing or bleaching action and thus a beneficial effect on color and storage life of grapefruit juice (Boyd and Peterson, 1945; Tressler and Joslyn, 1961). The National Food Processors Association (1968), specifically recommended the use of tin cans as containers for white grapefruit juice and segments "as a means of helping to retain the normal light color, which otherwise tends to darken during processing and storage." Pasteurized reconstituted white grapefruit-watermelon mixture stored in tin cans at 0$^{o}$ and 27$^{o}$C exhibited little change after 3 months of storage (Boyd and Peterson, 1945; National Food Processors Association, 1968).

Table 19. ANOVA of lightness (L) value, chroma (c) and hue angle (θ) of pasteurized reconstituted grapefruit-watermelon mixtures, as influenced by can type (C), temperature (T) and storage duration (Ti)

| Variable | Source | df | SS | MS | F | PR>F |
|---|---|---|---|---|---|---|
| L | C | 1 | 2.3000 | 2.3000 | 29.05 | 0.0001 |
| | T | 1 | 0.0525 | 0.0525 | 0.66 | 0.4189 |
| | CxT | 1 | 3.2411 | 3.2411 | 40.94 | 0.0001 |
| | Ti | 6 | 2.1374 | 0.3562 | 4.50 | 0.0009 |
| | CxTi | 6 | 3.0140 | 0.5023 | 3.65 | 0.0001 |
| | TxTi | 6 | 0.1683 | 0.0280 | 0.35 | 0.9044 |
| | CxTxTi | 6 | 2.0564 | 0.3427 | | |
| | Error | 56 | 4.4333 | 0.0792 | | |
| | Total | 83 | 17.4032 | | | |
| C | C | 1 | 4.8586 | 4.8586 | 176.68 | 0.0001 |
| | T | 1 | 5.0562 | 5.0562 | 183.86 | 0.0001 |
| | CxT | 1 | 5.1478 | 5.1478 | 187.19 | 0.0001 |
| | Ti | 6 | 6.3534 | 1.0622 | 38.62 | 0.0001 |
| | CxTi | 6 | 2.0041 | 0.3340 | 12.14 | 0.0001 |
| | TxTi | 6 | 2.4772 | 0.4129 | 15.01 | 0.0001 |
| | CxTxTi | 6 | 1.8331 | 0.3055 | 11.11 | 0.0001 |
| | Error | 56 | 1.5420 | 0.0275 | | |
| | Total | 83 | 29.2924 | | | |
| θ | C | 1 | 2.0765 | 2.0765 | 21.36 | 0.0001 |
| | T | 1 | 0.1824 | 0.1824 | 1.87 | 0.1761 |
| | CxT | 1 | 6.3934 | 6.3934 | 65.78 | 0.0001 |
| | Ti | 6 | 25.6527 | 4.2754 | 43.98 | 0.0001 |
| | CxTi | 6 | 1.2658 | 0.2110 | 2.17 | 0.0594 |
| | TxTi | 6 | 0.8251 | 0.1375 | 1.34 | 0.2252 |
| | CxTxTi | 6 | 3.6723 | 0.6120 | 6.28 | 0.0001 |
| | Error | 56 | 5.4425 | 0.0972 | | |
| | Total | 83 | 45.5108 | | | |

Table 20. Mean lightness (L) value, chroma (c) and hue angle (θ) of pasteurized reconstituted grapefruit-watermelon mixtures, as influenced by can type (C), temperature (T) and storage duration (Ti).

| | L | | | | C | | | | θ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ti (weeks) | $C_1T_1$ | $C_1T_2$ | $C_2T_1$ | $C_2T_2$ | $C_1T_1$ | $C_1T_2$ | $C_2T_1$ | $C_2T_2$ | $C_1T_1$ | $C_1T_2$ | $C_2T_1$ | $C_2T_2$ |
| 0 | 45.2ab | 45.2a | 45.7a | 45.7a | 21.5c | 21.5b | 21.6c | 21.6c | 70.5a | 70.5a | 70.5a | 70.5a |
| 1 | 45.4a | 45.3a | 45.3b | 45.0ab | 22.0a | 21.9a | 21.9ab | 22.0c | 69.8b | 69.9c | 69.8b | 69.8ab |
| 2 | 45.1ab | 45.5a | 45.2b | 44.7bc | 22.1a | 22.1a | 22.0ab | 22.9b | 68.7c | 68.9e | 69.0c | 68.4de |
| 3 | 44.8b | 45.7a | 45.1bc | 44.0c | 22.1a | 22.0a | 21.9b | 23.5a | 68.8c | 69.6d | 69.6b | 67.7e |
| 4 | 45.3a | 45.6a | 45.1bc | 44.7bc | 21.9ab | 22.0a | 21.9ab | 23.3ab | 69.7b | 70.3ab | 69.8b | 69.4bc |
| 5 | 45.0a | 45.6a | 45.3b | 44.8b | 21.9ab | 22.0a | 22.1a | 23.4a | 69.5b | 70.3ab | 69.9b | 69.1bcd |
| 6 | 45.3a | 45.6a | 44.9c | 44.6bc | 21.8c | 22.0a | 21.9ab | 23.6a | 69.5b | 70.1bc | 69.6b | 68.7cd |

$C_1$ = tin can, $C_2$ = enamel can

$T_1 = 0^{o}C$, $T_2 = 27^{o}C$

Each mean is an average of 3 replicates.

Means within each column containing same letter are not significantly different at 0.05 level.

Fig. 22 - Effect of can type (C), temperature of storage (T) and length of storage (Ti) on L value of pasteurized reconstituted white grapefruit-watermelon mixture

$C_1$ = tin

$C_2$ = enamel

$T_1$ = 0°C

$T_2$ = 27°C

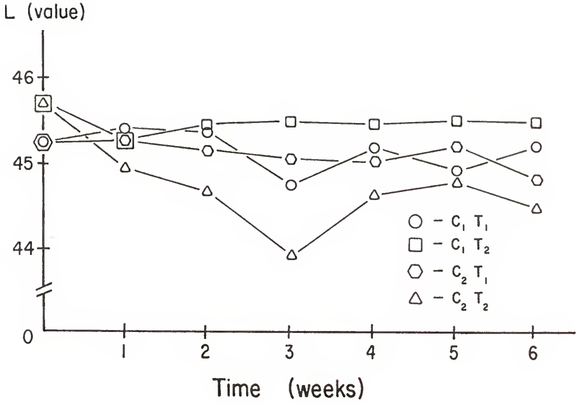

L (value)
46
45
44
0
1
2
3
4
5
6
Time (weeks)
○ – $C_1$ $T_1$
□ – $C_1$ $T_2$
⬡ – $C_2$ $T_1$
△ – $C_2$ $T_2$

Fig. 23 - Effect of can type (C), temperature of storage (T) and length of storage (Ti) on saturation index of pasteurized reconstituted white grapefruit-watermelon mixture

$C_1$ = tin

$C_2$ = enamel

$T_1$ = 0°C

$T_2$ = 27°C

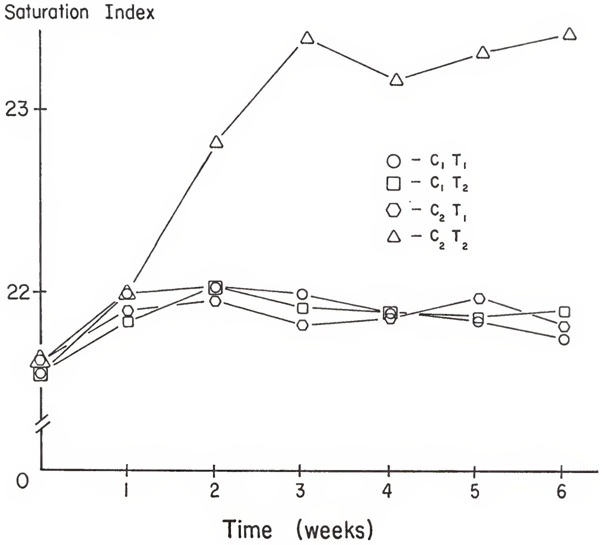

Saturation Index
23
22
0
1
2
3
4
5
6
Time (weeks)
○ – C1 T1
□ – C1 T2
⬡ – C2 T1
△ – C2 T2

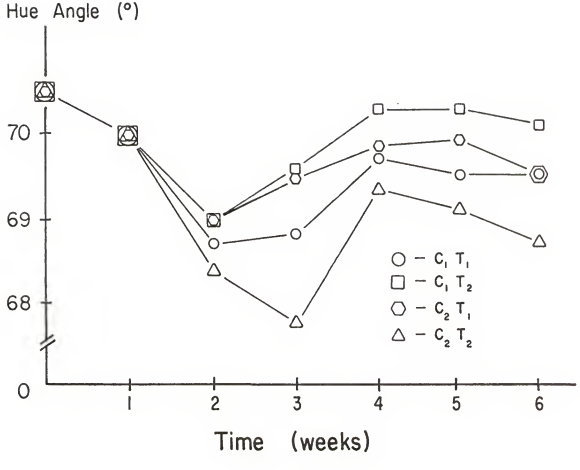
Fig. 24 - Effect of can type (C), temperature of storage (T) and length of storage (Ti) on hue angle of pasteurized reconstituted white grapefruit-watermelon mixture

$C_1$ = tin

$C_2$ = enamel

$T_1$ = 0°C

$T_2$ = 27°C


Hue Angle (°)
70
69
68
0
1
2
3
4
5
6
Time (weeks)
○ – $C_1 T_1$
□ – $C_1 T_2$
⬡ – $C_2 T_1$
△ – $C_2 T_2$

As a general conclusion, an enamel can is not recommended for storing pasteurized reconstituted white grapefruit-watermelon mixtures at relatively high temperature. Product should be stored in enamel or other containers such as glass, plastic and waxed carton and should be kept at low temperatures if detinning is of much concern. Tin cans are satisfactory at both low and high temperatures. However, lower temperatures should be used if much detinning is to be avoided. The Codex Alimentarus recently proposed a limit of about 150 ppm tin in orange juice for infants (Berry and Veldhuis, 1977). Kefford et al. (1959) indicated that tin content may reach 150 to 250 ppm in canned orange juices stored at about 30°C for 6 months or longer.

## Watermelon Seed Protein Studies

### Protein Extraction

Protein extracted from whole seeds had a light brown color. This could be due to contamination by tannin substances from the hull and/or due to protein denaturation and darkening at the high pH values used for extraction (Fan and Sosulski, 1974).

The hull should be removed and the kernel alone should be used for protein extraction in order to obtain a lighter product. A slightly lower extraction pH (e.g. pH 9) may be attempted if brown discoloration still persists, taking note that pH is one of the major factors controlling protein extractability. Any change from optimal condition should be carefully weighed.

### Proximate Analysis of Watermelon Seed Protein Concentrate (WPC)and Kernel

Freeze-dried WPC contained much less moisture, fat and ash and a little more carbohydrate than those of the kernel but more than twice as much protein (Table 21). Protein content of WPC and kernel is definitely higher than that of many other seeds.

## Functional Properties of WPC

### Solubility

Solubility of WPC was dependent on pH and is shown in Fig. 25. The minimum and maximum solubilties occurred at pH 3 and pH 10, respectively. Solubility was about 65% at pH 7 and is about the same as that of freeze-dried peanut protein concentrate but a little better than that of freeze-dried soybean protein concentrate extracted under similar conditions (Ahmed and Schmidt, 1979).

### Emulsifying capacity

Emulsifying capacity (EC) of WPC was 270.4 ml oil/g protein. Under similar conditions EC of freeze-dried peanut protein concentrate and soybean protein concentrate were 22.4 and 41.4 ml oil/100 mg protein, respectively (Ahmed and Schmidt, 1979).

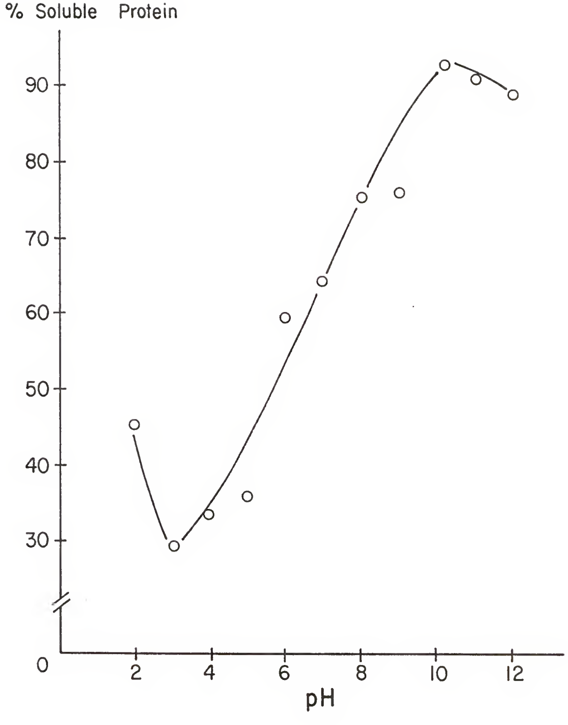
The emulsifying capacities of many proteins have been investigated because of their potential use in food emulsions, especially in salad dressing and comminuted meat products (Borton et al., 1968). Crenwelge et al. (1974) compared the EC of 4 protein preparations, cottonseed flour (57.5% protein), soybean concentrate (67.5% protein), decolorized bovine hemoglobin (90.1% protein) and low-heat nonfat dry milk (35.4% protein), over a range of protein concentrations and conditions. They found that the rate of oil addition, pH, protein concentration and protein solubility had pronounced effects on EC and the effects varied with the kind of protein used, making it difficult to compare EC of

Table 21. Proximate analysis of watermelon seed protein concentrate (WPC) and kernel.

| Percentage | Moisture | Fat | Protein | Ash | CHO[y] |
|---|---|---|---|---|---|
| WPC | 2.6 | 11.1 | 64.9 | 2.7 | 18.7 |
| Kernel | 4.5 | 44.8 | 30.7 | 4.3 | 15.7 |

[y] Carbohydrate by difference

Fig. 25 - Effect of pH on solubility of watermelon protein concentrate in aqueous buffer solutions


% Soluble Protein
90
80
70
60
50
40
30
0
2
4
6
8
10
12
pH

different proteins. Kinsella (1976) reported that equipment design, shape of container, speed of blending, temperature, kind of oil used, salt (type and concentration), sugars and water content also affect the emulsifying capacity of proteins. Furthermore, the method of expressing EC is not uniform.

### Foaming capacity and foaming stability.

Values found in the present study, 55.0 ml for foaming capacity and 1.5 ml for foaming stability were very low, possibly due to the presence of an appreciable amount of coarse particles present in WPC. The average foaming capacity and foaming stability of glandless cottonseed protein isolate precipitated at the same pH and spray dried were 74 ml and 20 ml, respectively (Lawhon and Cater, 1971). Spray drying may be responsible for higher values, because spray-dried peanut and soybean protein concentrates had higher values than freeze-dried concentrates (Ahmed and Schmidt, 1979). Other factors such as higher protein concentration and finer particles may also contribute to the superiority of glandless cottonseed isolate. The method of determination of Lawhon and Cater (1971), although rudimentary, has been popular because it requires no sophisticated equipment and was adopted for this study. Foam formation and breakdown are highly kinetic processes; hence the main disadvantage of this method lies principally in the variable speed and force of forming foams by hand shaking.

## Amino Acid Profile and Protein Quality of WPC and Kernel

The amino acid profile, amino acid score (AAS) and the essential amino acid index (EAA index) are shown in Table 22. Tryptophan is

Table 22. Amino acid content (g/100 g protein) of watermelon seed kernel and protein concentrate (WPC).

| | Kernel | WPC |
|---|---|---|
| Aspartic acid | 8.50 (88.5)[a] | 8.50 (88.5) |
| Threonine | 4.31 (84.3) | 3.61 (70.6) |
| Serine | 5.53 (72.6) | 5.70 (74.8) |
| Glutamic acid | 17.21 (135.3) | 16.56 (130.4) |
| Proline | 5.97 (143.8) | 6.38 (151.3) |
| Glycine | 9.86 (297.9) | 8.89 (168.6) |
| Alanine | 7.05 (119.3) | 6.94 (117.4) |
| Valine | 4.83 (70.7) | 5.36 (78.5) |
| Cystine | 1.18 (48.6) | 1.41 (58.0) |
| Methionine | 2.27 (67.8) | 2.67 (79.7) |
| Isoleucine | 3.88 (61.9) | 4.22 (67.3) |
| Leucine | 6.25 (71.0) | 6.63 (75.3) |
| Tyrosine | 2.54 (61.2) | 2.49 (60.0) |
| Phenylalanine | 4.29 (75.0) | 4.30 (75.3) |
| Lysine | 2.87 (41.2) | 3.02 (43.4) |
| Histidine | 2.08 (85.6) | 2.09 (86.0) |
| Arginine | 11.35 (186.7) | 11.33 (186.3) |
| EEA | 73 | 69 |

[a] Values in parentheses are amino acid scores using whole hen egg protein as reference protein (FAO, 1970)

missing due to its destruction during acid hydrolysis of the protein. This method was adopted mainly because of the knowledge that tryptophan is not the limiting amino acid. Recent work in Africa (Oyenuga and Fetuga, 1975) indicated that tryptophan content in watermelon seed protein is very high, 57 mg/g total essential amino acids as compared to 32 mg/g total essential amino acids in whole hen egg. Its computed AA score would be (57/32) x 100 = 178. Lysine was reported to be the limiting amino acid (Stafford and Oke, 1977). Lysine also had the lowest AAS of all the essential amino acids for both kernel and WPC in this study (Table 22). Lysine AAS can then be considered as chemical score of watermelon seed protein. Essential amino acid indices (Oser, 1965) which take into account all essential amino acids, were also calculated as a chemical score tends to underestimate the quality of a protein. Their values were indeed higher than the chemical scores, 73 vs 41.2 for kernel and 69 vs 43.4 for WPC.

King (1941) and Umoh and Oke (1974) reported that watermelon seeds are highly digestible. Watermelon protein could be used for amino acid supplements of protein sources low in tryptophan and having some threonine and phenylalanine, but not for those low in lysine such as cereals.

High amino acid scores were found for arginine, 186, and histidine, 86, in both kernel and WPC. These amino acids are essential for infants; thus addition of watermelon seed protein to baby food may be beneficial.

## Watermelon Seed Oil Studies

### Oil Content of Whole Seed and Kernel

Oil contents of both whole seed (hull and endosperm) and kernel (endosperm) are given in Table 23. Whole seed oil content was not

Table 23. Watermelon seed oil content (% w/w)

| Method | Whole seed[y] | Kernel[z] |
|---|---|---|
| Bligh and Dyer | -- | 50 ± 0.4 |
| Goldfish | 20.9 ± 1.2 | 44.8 ± 0.8 |

[y] Hull and endosperm

[z] Endosperm

determined with the Bligh and Dyer method, because the hull was too hard to be comminuted by the blender blades. The oil content of the kernel as determined by the Bligh and Dryer method was higher than that obtained with the Goldfish apparatus. The kernel was chopped and extracted inside the blender with little loss during filtration and transfer to a separatory funnel. The oil yield may approach the theoretical value (Pomeranz and Meloan, 1971). The Goldfish value was lower, due to possible loss of oil during grinding and incomplete extraction. However, the Goldfish apparatus is still considered as one of the best continuous fat extractors. Whole seeds had a much lower percentage oil content than the kernel because the hull represented more than 50% of the total weight.

The oil content of watermelon kernel compares well with the amounts present in palm oil and peanut, 50%,but higher than in cottonseed, 34%, sunflower, 29%, kapok, 25%, soybean, 25% (Swern, 1964c), and cocoa bean, 43%, (Oyenuga, 1975).

### Separation and Classification of Lipids

Relative percentages of the 3 classes of lipids are given in Table 24. Neutral lipids represent almost the totality of watermelon seed oil, whereas glyco- and phospholipids, present in equal amounts, share only about 1% of total lipids. This small amount of phospholipids and the tough hull may be responsible for the stability of oil against oxidative rancidity. Possible occurrence of natural antioxidants such as tocopherols may also play a role in prolonging the storage life.

### Fatty Acid Composition of Neutral Lipid and Total Lipid

The neutral lipid fraction and total lipid (Table 25) contained the same type and almost the same amount of fatty acids (FA). Trace

Table 24. Lipid classes of watermelon seed oil

| Lipid | Relative percentage |
|---|---|
| Neutral | 98.8 ± 0.1 |
| Glyco- | 0.6 ± 0.2 |
| Phospho- | 0.6 ± 0.1 |

Table 25. Fatty acid composition of watermelon seed oil (% of total)

| Fatty acid | Neutral lipid[y] | Total lipid[z] |
|---|---|---|
| $C_{16}$ | 11.9 ± 0.5 | 12.15 ± 0.04 |
| $C_{18}$ | 6.2 ± 0.3 | 5.85 ± 0.06 |
| $C_{18:1}$ | 18.1 ± 0.2 | 18.75 ± 0.09 |
| $C_{18:2}$ | 64.0 ± 0.4 | 63.25 ± 0.16 |

[y] Present study as per Metcalf, L.D. et al. (1966)

[z] Determined by USDA Winter Haven Laboratory. $C_{14}$ $C_{15}$, $C_{17}$, $C_{18:3}$ and $C_{20}$ were found in trace amounts.

amounts of FA in $C_{14}$, $C_{15}$, $C_{17}$, $C_{18:3}$ and $C_{20}$ found in total lipid may have come from the polar lipid fraction or the instrument used was more sensitive than the one used to analyze the neutral lipid fraction.

Results from both fractions and the 4 distinct peaks in the chromatograms (Figs. 26, 27) confirmed that watermelon seed oil FA consist of palmitic, stearic, oleic and linoleic acids, with the latter 2 predominating. This oil falls then in the group of oleic-lineoleic acid oils, which comprise cottonseed, peanut, sesame, corn, sunflower, safflower, olive, palm oil and rice bran oils (Swern, 1964b). Watermelon seed oil is highly unsaturated, with more than 63% consisting of lineoleic acid. Only safflower of all of the oils cited contains a higher amount of lineoleic acid, 73 to 79%. The others contain little linoleic acid but have much higher amounts of oleic acid. Moderate amounts of linoleic acid were found in cottonseed, 51%, corn, 34 to 62% and rice bran, 29 to 42% (Swern, 1964c). The ratio of unsaturated to saturated fatty acids of watermelon seeds was 4.6 to 1.

Watermelon seed oil contains no linolenic or other more unsaturated FA; therefore it is expected to be free from the tendency of reversion. Reversion is a property of certain fats which, after being refined and rendered odorless and flavorless, become oxidized, and develop objectionable flavors. This property is characteristic of soybean oil whose affected flavor has been described as beany, grassy, painty or fishy (Dugan, 1976).

## Physical and Chemical Properties of Watermelon Seed Oil

Physical and chemical properties of watermelon seed oil are given in Table 26. The high refractive index, $R^{40} = 1.466$, and high iodine

Table 26. Physical and chemical properties of watermelon seed oil

| | |
|---|---|
| Refractive index $R^{40}$: Cold Extract | 1.466±0.000 |
| Ether Extract | 1.466±0.000 |
| Specific gravity at 25/25°C | 0.962±0.004 |
| Unsaponifiable matter (%) | 0.820±0.020 |
| Saponification value (mg KOH/g sample) | 181.500±0.300 |
| Iodine value (I.V.) (cg iodine absorbed/g sample | 123.500±0.700 |
| Peroxide value (meq of peroxide/1000 g sample) | 0.280±0.004 |
| Free fatty acid (%, as oleic) | 1.160±0.080 |

Fig. 26 - Chromatogram of fatty acid methyl esters of watermelon seed neutral lipids. (Chromatograph = Varian aerograph 1520, column = glass coil, 1524 mm x 4 mm ID, packing = 10% EGSS-x on 100/120 Gas Chrom Q, temperature = 185°C isotherm, flame ionization detector at 240°C, injector at 240°C, flow rate = 40 ml He/min, solution = 0.5 micromole $CHCl_3$, integration = Digital Integrator CSI38.)

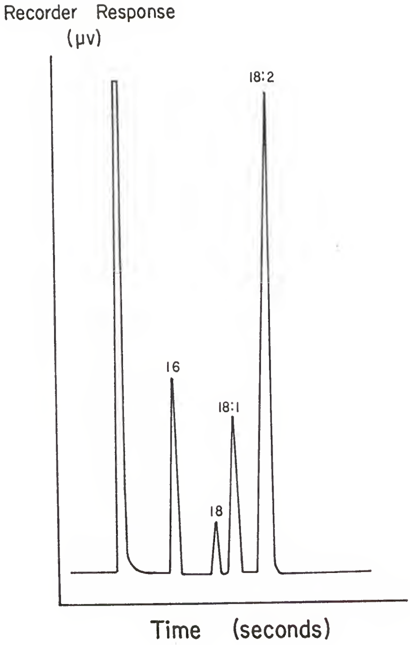
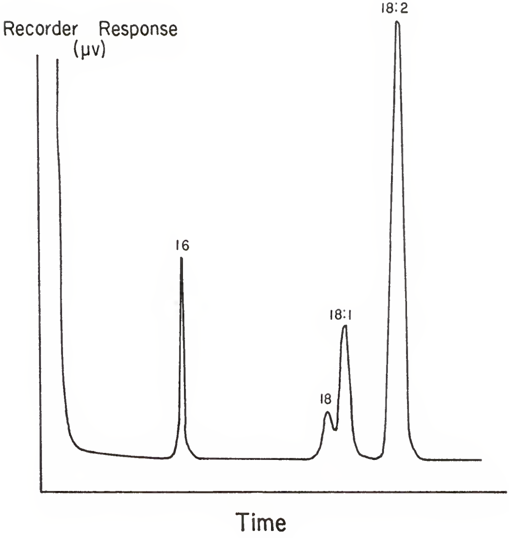

Recorder Response
(µv)
16
18
18:1
18:2
Time (seconds)

Fig. 27 - Chromatogram of fatty acid methyl esters of watermelon seed total lipid. (Chromatograph = Hewlett Packard 7620A, column= 1,828.8 mm x 76. 2 mm glass U-tube, packing= 3% SP1000 on 100/120 Gas Chrom Q, temperature= 150°C isotherm, flame ionization detector at 270°C, injector at 270°C, flow rate = 80 ml He/min, solution = 1 microliter hexane, integrator = Autolab Sys IV Electronic.)


Recorder Response
(μv)
16
18
18:1
18:2
Time

value, IV = 123.5, support its highly unsaturated nature, 19% oleic and 63% linoleic acids. This correlation has been observed by Dugan (1976) as a general property of fat. For example, less unsaturated peanut oil, 53% oleic + 25% linoleic and palm oil, 52% oleic + 8.2% linoleic, have lower values, $R^{40}$ = 1.4612 and IV = 97 for peanut oil and $R^{40}$ = 1.453 and IV = 51 for palm oil, while more unsaturated sunflower oil 34% oleic + 57% linoleic and safflower, 14% oleic + 78% linoleic, have higher values, $R^{40}$ = 1.4736 and IV = 131 for sunflower and $R^{40}$ = 1.4725 and IV = 145 for safflower. The values used in this comparison were reported by Swern (1964c), but the R values were not determined at 40°C. Therefore, temperature adjustments were necessary and made according to the official methods of AOCS (1976).

Specific gravity of watermelon seed oil is slightly higher than that of common oils in the same group, due to a higher degree of unsaturation. Unsaponifiable matter of watermelon seed oil, 0.82%, is higher than that of cottonseed oil, 0.54%, about the same as that of palm oil, 0.80%, but lower than that of the rest of the group. The unsaponifiable matter consists mainly of phytosterols in vegetable oils. These are relatively inert and do not contribute to any important property of the oil. Their recovery is of some interest in some cases because they constitute precursors for synthesis of sex hormones and vitamin D.

The saponification value of watermelon seed oil, 181.5 mg KOH/g oil, known also as saponification number (SN), is the lowest of the group. Therefore, it requires the least amount of alkali to saponify a unit weight of oil. This property might be useful in soap-making industry. An analogous but different term is the saponification equivalent (SE), which is defined as the number of grams of fat-saponified by 1 mole of potassium hydroxide or 56,104 mg. Therefore, 56,104/SE potassium hydroxide are required to saponify 1 g of fat. Consequently, it is possible to write 56,104/SE = SN, or as Swern (1964a) has reported

(saponification number) x (saponification equivalent) = 56,104.

The peroxide number or peroxide value of watermelon seed oil, 0.28 meq peroxide/1000 g oil is low, considering the fact that the determination was made 1.5 years after storage and air drying. This further evidences the stability of watermelon seed oil in intact systems.

The free fatty acid (FFA) content of watermelon seed oil, 1.16% as oleic, falls within the range of 0.25 to 1.5% for the common oleic-linoleic acid oils. Percentage FFA could be used to measure the extent of hydrolysis that has occurred in a fat if the original content were known, Another term which expresses essentially the same property is the acid or neutralization number. It is defined as the number of milligrams of potassium hydroxide required to neutralize the FFA in 1 g of fat. It is related to the FFA content by the following formula

1 unit of acid number = 0.503% FFA (Swern, 1964a).

All above properties are important for establishing standards of identity of fats as well as providing useful information for their utilization.

# SUMMARY AND CONCLUSIONS

'Charleston Gray' watermelon juice was extracted and concentrated with freeze concentration, low pressure evaporation and thermally accelerated short time evaporation (TASTE). Quality of the concentrate and the reconstituted juices was evaluated. Possible utilization of the concentrate in a fruit beverage was examined. Proteins and oil were extracted from watermelon seeds and their chemical and physical properties were determined. Results of these investigations show that:

1. The TASTE method produced the best concentrate in terms of total soluble solids content, $65^{o}$ Brix, and overall efficiency, flavor and color.

2. Watermelon concentrate exhibited a pseudoplastic flow behavior which was time independent. Apparent viscosities of this concentrate were lower than those of orange and grapefruit juice concentrates.

3. A fruit punch containing watermelon (W): orange (O): pineapple (P) juice mixture was sensorially evaluated by laboratory and small-scale consumer tests, the best combinations of the different types of fruit punch being

0.40W:0.30 O:0.30P for 100% (15:1) juice

0.54 W:0.23 O:0.23P for 50% (15:1) juice

0.54 W:o.23 O:0.23P for 10% (25:1) juice

4. No statistical differences were found in acceptability ratings among the different types of fruit punch provided that formulations and Brix:Acid ratios were appropriate.

5. No statistical differences were found in sensory acceptance scores of formulations containing watermelon juice in amounts ranging from 30% to 80% of the juice fraction.

6. Color of best commercial pink grapefruit juice could be produced by adding a small amount of watermelon concentrate, 1.0 or 1.5 cc, to white grapefruit juice, 100 cc.

7. Color stability of watermelon:grapefruit juice mixture was evident under simulated home refrigeration storage for 15 days, supermarket marketing conditions at $0^o$ and at $27^oC$ for 6 weeks and beverage manufacture storage conditions at $-18^oC$ and $2^oC$, and $10^oC$.

8. Addition of small amounts of watermelon concentrate improved the flavor of white grapefruit juice.

9. Watermelon seeds are rich in protein, 30.7% and oil, 44.8%.

10. The limiting amino acid in seed protein is lysine.

11. The essential amino acid index for watermelon seed protein was 0.73 using whole hen egg as the reference protein.

12. Watermelon seed protein was 65% soluble at pH 7.0 and reached maximum solubility at pH 10.

13. The major component of watermelon seed lipids was the neutral lipids, 98.8%. The major fatty acid was linoleic acid, 64.0%, followed by oleic acid, 18.1%. The ratio of unsaturated to saturated fats was 4.6:1.

# REFERENCES

Ahmed, E. M. and Schmidt, R. H. 1979. Functional properties of peanut and soybean proteins as influenced by processing methods. Peanut Science. In Press.

Akher, A. M., Alian, A. and Khalof-Allah, A. 1974. Production of alcoholic beverages from watermelon juice. II. Chemical changes during fermentation and aging of fermented watermelon juice. Egypt. J. Food Sci. 2(2):119. In Chem. Abstr. 1976, 85(3):18 992.

Anderson, J. A. and Alcock, H. W. 1954. "Storage of cereal grains and their products," Amer. Assoc. Cereal Chemists, St. Paul, Min.

Anonymous. 1916. Watermelon seeds from the Sudan. Bull. Imp. Inst. 14:160. In Chem. Abstr. 1916, 10(21):3171.

Anonymous. 1964. Sensory testing guide for panel evaluation of foods and beverages. Food Technol. 18(8):25.

Anonymous. 1975. The vegetable industries. In "Agricultural Growth in an Urban Age," p. 51. Institute of Food and Agricultural Sciences, Univ. of Florida, Gainesville.

Anonymous. 1978. Common or usual names for nonstandardized foods. In "The Almanac of the Canning, Freezing, Preserving Industries," p. 119. 63rd ed., Westminster, Maryland.

AOAC. 1970. "Official Methods of Analysis," 11th ed., Association of Official Agricultural Chemists, Washington, D.C.

AOCS. 1976. "Official and Tentative Methods," 3rd ed., Amer. Oil Chemists Society.

Baker, D., Neustadt, M. H. and Zeleny, L. 1959. Relationship between fat acidity values and types of damage in grain. Cereal Chem. 36:308.

Baltaga, S. V., Grimpel, M. S. and Arasimovich, V. V. 1961. Production of pectin from watermelon. Inst. Oroshaemogo Zemledeliya i Ovoshchevodstava 3:240. In Chem. Abstr. 1963, 59(5):5701.

Barr, A. J., Goodnight, J. H. Sall, J. P. and Helwig, J. T. 1976. "A User's Guide to SAS76," SAS Institute Inc., Raleigh, N.C.

Bengtsson, K. and Helm, E. 1946. Principles of taste testing. Wallerstein Lab. Commun. 9:171.

Berry, R. E. and Veldhuis, M. K. 1977. Processing of oranges, grapefruit and tangerines. In "Citrus Science and Technology" Nagy, S., Shaw, P. E. and Veldhuis, M. K., Eds., vol. 2, 1977. AVI Publishing Co., Inc., Westport, Conn.

Bligh, E. G. and Dyer, W. J. 1959. A rapid method of total lipid extraction and purification. Can. J. Biochem. Physiol. 37 (8):911.

Block, R. L. and Mitchell, H. H. 1947. The correlation of the amino acid composition of proteins with their nutritive value. Nutr. Abstr. Rev. 16:249.

Borton, R. J., Webb, N. B. and Bratzler, L. J. 1968. Emulsifying capacity and emulsion stability of dilute meat slurries from various meat trimmings. Food Technol. 22:506.

Boyd, J. M. and Peterson, G. T. 1945. Quality of canned orange juice. Ind. Eng. Chem. 37:370.

Brittin, W. A. 1976. FDA acts on food color listings. Food Prod. Dev. 10(9):96.

Carpenter, J. A. and Saffle, R. L. 1964. A simple method of estimating the emulsifying capacity of various sausage meats. J. Food Sci. 29:774.

Carter, R. D. 1965. New evaporator boosts concentrated orange juice production. Food Manufacture 40(11):48.

Carter, R. D. 1978. Reconstituted Florida Orange Juice. Production/ Packaging/Distribution. Technical Manual, Fla. Dept. Citrus, Lakeland, Florida.

Carter, R. D. 1979. Private communication. Agricultural Research and Educational Center, Lake Alfred, Florida.

Cartwright, L. C., Snell, C. T., and Kelley, P. H. 1952. Organoleptic panel testing as a research tool. Anal. Chem. 24:503.

CFR. 1977. Code of Federal regulations, Title 21, Foods and Drugs, Parts 100-199, p. 258.

Cochran, W. G. and Cox, G. M. 1957. Balanced and partially balanced incomplete block designs. In "Experimental Designs," 2nd ed., p. 439. Wiley Publications in Statistics, New York. John Wiley & Sons, Inc., London, Sydney.

Cook, R. W. 1963. High temperature short time evaporator. Proc. Citrus Eng. Conf., Sect. Am. Soc. Mech. Eng. 9:1.

Cook, R. W. 1964. Vacuum. evaporator. U.S. Pat. 3, 141,807.

Cornell, J. A. and Ott, L. 1975. The use of gradients to aid in the interpretation of mixture response surfaces. Technometrics 17(4):409.

Crall, J. M. 1971. Smokylee. A high quality watermelon with resistance to anthracnose and fusarium wilt. Fla. Agr. Expt. Sta., Cir. S-211.

Crenwelge, D. D., Dill, C. W., Tyba, P. T. and Landmann, W. A. 1974. A comparison of the emulsification capacity of some protein concentrates. J. Food Sci. 39:175.

Davies, B. H. 1976. Carotenoids. In "Chemistry and Biochemistry of Plant Pigments," Goodwin, T. W., Ed., 2nd ed., vol. 2, p. 38. Academic Press, London, New York, San Francisco.

Davies, M. G. and Thomas, A. J. 1973. An investigation of hydrolytic techniques for the amino acid analysis of foodstuffs. J. Sci. Fd. Agric. 24:1525.

D'Eaubonne, G. 1965. La Federation internationale des producteurs de jus de fruits. Son Action. Ses interventions. Son avenir. In "VIth International Fruit Juice Congress," International Federation of Fruit Producers, Luzern, Switzerland.

Dougherty, M. H., and Fisher, J. F. 1977. Quality of commercial, canned, single-strength grapefruit juice produced in Florida during the 1975-1976 and 1976-1977 citrus seasons. Proc. Fla. State Hort. Soc. 90:168-170.

Dugan, L., Jr. 1976. Lipids. In "Principles of Food Science. Part I. Food Chemistry," Fennema, O. R., Ed., p. 139. Marcel Dekkar, Inc., New York and Basel.

Ecky, E. W. and Miller, L. P. 1954. Introduction. In "Vegetable Fats and Oils," p. 1. Reinhold Publishing Corp., New York.

Fan, T. Y. and Sosulsky, F. W. 1974. Dispersibility and isolation of proteins from legume flours. Can. Inst. Food Sci. Tech. 7:256.

FAO. 1970. Eggs. In "Amino Acid Content of Foods," p. 122. Food and Agriculture Organization of the United Nations, Rome, Italy.

Farrall, A. W. 1976. Evaporating and drying equipment. In "Food Engineering Systems," p. 181. AVI Publishing Co., Inc., Westport, Conn.

Federal Register. 1972. Diluted orange juice beverages. Federal Register 37(49):5224.

Federal Register. 1973. Diluted orange juice beverages; notice staying identity standards and order establishing a common or usual name. Federal Register 38(49):6968.

Fefer, I. M., Mindlin, M. Z. and Prokopovich, N. N. 1954. Farmakol. i Toksikol. 17(5):50. In Chem. Abstr. 1955, 49(11):7813.

Feinberg, B. 1964. Concentration by evaporation. In "Food Processing Operations. Their management, Machines, Materials, and Methods," Joslyn, M. A. and Heid, J. L., Eds., p. 309. AVI Publishing Co., Inc., Westport, Conn.

Fla. Dept. Citrus. 1979a. Frozen concentrated orange juice. Florida Department of Citrus Official Rules, Chap. 20-64.07 (revised 1/1/75).

Fla. Dept. Citrus. 1979b. Institutional Packs of 4 + 1 frozen concentrated orange juice. Florida Department of Citrus Official Rules, Chap. 20-67.01 (revised 1/1/75).

Francis, F. J. and Clydesdale, F. M. 1975. Preface. In "Food Colorimetry: Theory and Applications," p. V. AVI Publishing Co., Inc., Westport, Conn.

Girgis, P. and Said, F. 1968. Lesser known Nigerian edible oils and fats. I. Characteristics of melon seed oils. J. Sci. Food Agric. 19:615.

Gusina, G. B., Markh, Z. A., Perlova, N. D., Bogdanova, Z. N. and Kotova, K. S. 1971. Dietetic juices made from cucurbitaceous fruits. Konserv. Ovoshchesush. Prom. 26(10):10. In Chem. Abstr. 1972, 76(9):57922.

Gusina, G. B. and Trostinskaya, L. O. 1974. Watermelon juice and pulp. Konserv. i Ovoshchesush. Prom. 3:17. In Food Sci. Technol. Abstr. 1974, 6(12):2020.

Hackler, L. R., Stillings, B. R. and Polimeni, R. J., Jr. 1967. Correlations of amino acid indexes with nutritional quality of several soybean fractions. Cereal Chem. 44:638.

Hegsted, D. M. 1974. Assessment of protein quality. In "Improvement of Protein Nutriture," p. 64. National Academy of Sciences, Washington, D. C.

Hegsted, D. M. 1977. Protein quality and its determination. In "Food Proteins," p. 247. AVI Publishing Co., Westport, Conn.

Heid, J. L., and Casten, J. W. 1961. Vacuum concentration of fruit and vegetable juices. In "Fruit and Vegetable Juice Processing Technology," Tressler, D. K. and Joslyn, M. A. Eds., p. 278. AVI Publishing Co., Inc., Westport, Conn.

Holbrook, M. L. 1875. "Eating for strength." Wood and Holbrook, New York. Quoted in Woodroof, J. G. and Phillips, G. F. 1974. "Beverages: Carbonated and Noncarbonated," p. 238. AVI Publishing Co., Inc., Westport, Conn.

Huggart, R. L. 1978. Private communications. Agricultural Research and Education Center, Lake Alfred, Florida.

Huggart, R. L. and Petrus, D. R. 1976. Color in canned commercial grapefruit juice. Proc. Fla. State Hort. Soc. 89:194.

Huggart, R. L. and Petrus, D. R. 1978. Private communications. Agricultural Research and Educational Center, Lake Alfred, Florida.

Huggart, R. L., Petrus, D. R., and Buslig, B. S. 1977. Color aspects of Florida commercial grapefruit juices, 1976-1977. Proc. Fla. State Hort. Soc. 90:173.

Huggart, R. L. and Ting S. V. 1970. Color standardization of pigmented grapefruit juices. Fla. State Hort. Soc. 83:27.

Ivancenko, D. and Tibensky, V. 1954. Honey production from melons of Slovak origin. Chem. Zvest 8:106. In Chem. Abst. 1955, 49(7): 5719.

Ivancenko, D. and Zajac, P. 1958. Honey substitute from watermelons of Slovak origin. I. Chemical composition. Chem. Zvest. 12:439. In Chem. Abstr. 1959, 53(1):603.

Jansen, G. R. 1973. Seeds as a source of protein for humans. In "Symposium: Seed Proteins," Inglett, G. E., Ed., p. 19. AVI Publishing Co., Inc., Westport, Conn.

Kefford, J. F. and Chandler, B. V. 1977. Squashes, cordials and comminuted citrus beverages. In "Citrus Science and Technology," Nagy, S., Shaw, P. E. and Veldhuis, M. K., Ed., Vol. 2, p. 346. AVI Publishing Co., Inc., Westport, Conn.

Kefford, J. F. and Christie, E. M. 1960. Sensory tests for colour, flavour, and texture. C.S.I.R.O. Food Preserv. Quart. 20:47.

Kefford, J. F., McKenzie, H. A. and Thompson, P. C. O. 1959. Effects of oxygen on quality and ascorbic acid retention in canned and frozen orange juices. J. Sci. Food Agric. 10:51.

Khaleque, K. A., Muazzam, M. G. and Ispahani, P. 1964. A simple method for the use of watermelon seed preparations in the estimations of blood urea. J. Clin. Pathol. 17(1):97.

Khattak, J. N., Hamdy, M. K. and Powers, J. J. 1965a. Utilization of watermelon juice. I. Alcoholic fermentation. Food Technol. 19(8): 1284.

Khattak, J. N., Hamdy, M. K. and Powers, J. J. 1965b. Utilization of watermelon juice. II. Acetic acid fermentation. Food Technol. 19(6):998.

King, T. E. 1941. Biological values of proteins in watermelon and pumpkin seeds. Chinese J. Physiol. 16(1):31. In Chem. Abstr. 1941, 35(13):4424.

Kinsella, J. E. 1976. Functional properties of protein in foods: a survey. Critical Reviews in Food Science and Nutrition. 7:219.

Kramer, A., Murphy, E. F., Briant, A. M., Wang and Kirkpatrick, M. E. 1961. Studies in taste panel methodology. J. Agr. Food Chem. 9:224.

Larmond, E. 1970. Methods for Sensory Evaluation of Food. Canada Department of Agriculture, Publication 1284, Food Research Institute Central Experimental Farm, Ottawa, Canada.

Larmond, E. 1973. Physical requirements for sensory testing. Food Technol. 27(11):28.

Lawhon, J. T. and Cater, C. M. 1971. Effect of processing method and pH of precipitation on the yields and functional properties of protein isolates from glandness cottonseed. J. Food Sci. 36:372.

Lime, B. J. and Griffiths, F. P. 1960. The preservation of pulp and participation of late season poorly colored red grapefruit juice. J. Rio Grande Valley Hort Soc. 14:88.

Lime, B. J., Stephens, T. S. and Griffiths, F. P. 1954. Processing characteristics of colored Texas grapefruit. I. Color and maturity studies of Ruby Red grapefruit. Food Technol. 8:566.

Lime, B. J., Stephens, T. S. and Griffiths, F. P. 1958. Production of canned pulp-fortified red grapefruit juice. U.S. Dept. Agri. ARS-72-12.

Little, A. C. 1975. Off on a tangent. J. Food Sci. 49:410.

Lowry, P. H., Rosebrough, N. J., Farr, A. L. and Randall, R. J. 1951. Protein measurement with the folin phenol reagent. J. Biol. Chem. 193:265.

Lutochir, S. N. and Untersuch, Z. 1927. The significance of watermelon syrup as a food product. Lebensm. 54:290. In Chem. Abstr. 1928, 22(9):1634.

Lutz, J. M. and Hardenburg, R. E. 1968. "The Commercial storage of fruits, vegetables, and Florist and Nursery Stocks," Agri. Handbook No. 66, U.S. Dept. of Agriculture.

Martin, A. M. and Coolidge, A. A. 1978. Proteins. In "Nutrition in Action," 4th ed., p. 151. Holt, Reinehart, and Winston, N.Y., Chicago, San Francisco, Atlanta, Dallas, Montreal, Toronto, London Sydney.

McCoy, D. C. 1973. Storage requirements and properties of perishable foods. In "Food Science," Potter, N. N. Ed., p. 194. AVI Publishing Co., Inc. Westport, Conn.

McLaughlan, J. M. 1974. Evaluation of standard rat assays. In "Nutrients in Processed Foods," White, P. L. and Fletcher, D. C. Eds., p. 69. American Medical Association, Publishing Sciences Group, Inc., Mass.

Meredith, F. I., Redman, G. H. and Griffiths, F. P. 1974. Changes in lycopene-carotene content and fruit quality of Hudson Red grapefruit. J. Rio Grande Valley Hort. Soc. 28:149.

Metcalf, L. D., Schmitz, A. A. and Pelka, J. R. 1966. Anal. Chem. 38(3):514.

Miller, G. A. and Lachance, P. A. 1977. Techniques in rat bioassays. In "Evaluation of Proteins for Humans," Bodwell, C. E. Ed., p. 149. AVI Publishing Co., Inc., Westport, Conn.

Milner, M., Scrimshaw, N. S. and Wang, D. I. C. 1978. "Protein Resources and Technology: Status and Research Needs," AVI Publishing Co., Inc., Westport, Conn.

Mitchell, H. H. 1924. A method for determining the biological value of protein. J. Biol. Chem. 58:873.

Moerck, K. E. and Ball, H. R. 1973. Lipids and fatty acids of chicken bone marrow. J. Food Sci. 38:978.

Montelaro, J. and Kostewicz, S. R. 1974. Watermelon Production Guide. Fla. Coop. Ext. Serv. Cir. 96E, Institute of Food and Agricultural Sciences, University of Florida, Gainesville.

Murdock, D. I. 1977. Microbiology of citrus products. In "Citrus Science and Technology," Nagy, S., Shaw, P. E. and Veldhuis M. K. Eds., vol. 2, p. 445. AVI Publishing Co., Inc. Westport, Conn.

Murdock, D. I. and Hatcher, W. S. 1975. Growth of microorganisms in chilled orange juice. J. Milk Food Tech. 38:393.

Murdock, D. I. and Hatcher, W. S. 1977. Effect of temperature on survival of yeast in 45° and 65° Brix orange concentrate. Proc. Fla. State Hort. Soc. 90:186.

Mustafa, A. I., Badi, S. M., Salma, R. B., Sayed, A. S. and Hussain, A. A. 1972. Studies on watermelon seed oil. Sudan Jour. of Food Sci. and Technol. 4:18. In Food Sci. Technol. Abstr. 1973, 5(2): 178.

Myskin, M. M. and Fokin, N. D. 1974. Frozen watermelon pulp. Konserv. Ovoshchesush. Prom. 1:10. In Food Sci. Technol. Abstr. 1974, 6(12):1771.

National Food Processors Association. 1968. Containers. In "Laboratory Manual for Food Canners and Processors," vol. 2, 3rd printing (1978), p. 409. AVI Publishing Co., Inc. Westport, Conn.

Nowlin, R. L. and Henwood, C. I., Jr. 1954. Flash evaporation now applied to grape juice concentrate. Wines and Vines 36(1):25.

Oberbacher, M. F., Ting, S. V. and Deszyck, E. J. 1960. Internal color and carotenoid pigments of Burgurdy grapefruit. Proc. Am. Soc.Hort. Sci. 75:262.

O'Connell, J. O. 1954. Instantaneous heating-flash evaporation. Food Processing 15(7):14.

Oke, O. L. 1965. Nutritive value of Nigerian watermelon. Nature 207:192.

Osborne, T. B., Mendel, L. B. and Ferry, E. L. 1919. A method of expressing numerically the growth-promoting value of proteins. J. Biol. Chem. 37:223.

Oser, B. L. 1965. Milk. In "Hawk's Physiological Chemistry," 14th ed., p. 368. McGray Hill Book Co., N.Y., Toronto, Sydney, London.

Oyenuga, V. A., and Fetuga, B. L. 1975. Some aspects of the biochemistry and nutritive value of the watermelon seed (citrullus valugaris, Schrad). J. Sci. Fed. Agric. 26:843.

Pangalo, K. 1960. Pectins from watermelons. Kartofel Ovoshchi 7:49. In Chem. Abstr. 1962, 56(4):3866.

Pangborn, R. M. 1967. Some aspects of chemoreception in human nutrition. In "The chemical senses and nutrition," Kare, M. R. and Maller, O., Ed., p. 45. Johns Hopkins Press, Baltimore, Md.

Pequeno, R. A. 1963. Semimicro method for determination of blood urea. Hospital 64:1365. In Chem. Abstr. 1964, 60(10):12353.

Pike, R. L. and Brown, M. L. 1975. Determination of nutrient needs: Energy, protein, minerals. In "Nutrition: An integrated approach," 2nd ed., p. 874. John Wiley & Sons, Inc., New York.

Pomeranz, Y. and Meloan, C. E. 1971. Lipids. In "Food Analysis: Theory and Practice," p. 578. AVI Co., Inc., Westport, Conn.

Porter, D. R., Bisson, C. S. and Allinger, H. W. 1940. Factors affecting the total soluble solids, reducing sugars and sucrose in watermelons. Hilgardia 13(2):31.

Potter, N. N. 1973. Food Dehydration and Concentration. In "Food Science," AVI Publishing Co., Inc., Westport, Conn.

Ramirez, M. V. and Monge, C. C. 1962. Glycerol extract of watermelon seeds as a source of urease. Acta Physiol. Latinoam. 12:210. In Chem. Abstr. 1963, 59(5):6659.

Rao, P. V. and Kupper, L. L. 1967. Ties in paired comparison experiments: A generalization of the Bradley-Terry model. J. Am. Statis. Association 62:194.

Rhee, K. C., Cater, C. M. and Mattil, K. F. 1972. Simultaneous recovery of protein and oil from raw peanuts in an aqueous system. J. Food Sci. 37:90.

Richard, M. 1971. Soft candied fruit. French Patent 2050177. In Food Sci. Technol. Abstr. 1972, 4(2):159.

Richard, M. 1974. Soft crystallized fruit. French Patent Application 2221082. In Food Sci. Technol. Abstr. 1975, 7(10):1426.

Rizek, R. L., Swope, D. A. and Peterkin, B. 1974. Trends in fresh fruit and vegetable consumption and their nutritional implications. In "Nutritional Qualities of Fresh Fruit and Vegetables," White, P. L. and Selvey, N., Eds., P. I. Futura Publishing Co., Inc., Mount Kisco, New York.

Robbins, R. C. 1978. Effect of ratio of enzymes to substrate on amino acids patterns released from proteins In Vitro. Int. J. Vit. Nutr. Res. 48:44.

Robson, J. R. K., Larkin, F. A., Sandretto, A. M. and Tadayyon, B. 1972. "Malnutrition. Its Causation and Control (with special reference to protein calorie malnutrition)," vol. 1, Gordon and Breach, New York, London, Paris.

Rodeghier, A. A. 1955. Determination of impurities in fats and oils. J. Am. Oil Chemists' Soc. 32:578.

Sackett, C. 1975. Fruit and Vegetable Facts & Points. United Fresh Fruit and Vegetables Association, Washington, D.C.

Salunkhe, D. K., and Bolin, H. R. 1974. Developments in technology and nutritive value of dehydrated fruits, vegetables, and their products. In "Storage, Processing, and Nutritional quality of fruits and vegetables," p. 39. CRC Press, Inc. Cleveland, Ohio.

Sao, C.M.T. and Potts, W. M. 1952. The analysis and characterization of the oil from the seed of Citrullus vulgaris. J. Amer. Oil Chemists' Soc. 29:444.

Scheffe', H. 1958. Experiments with mixtures. J. Roy. Stat. Soc. 20(2):344.

Schwabe, K. R. 1976. Amino acid patterns from proteins hydrolyzed by soluble and immobilized gastrointestinal enzymes In Vitro. Master's thesis, University of Florida, Gainesville, Florida.

Singh, P. P., Sharma, D. C. and Rathore, A. S. 1971. Urease activity in different varieties of watermelon seeds and its evaluation in blood urea determination. Asian. Med. J. 14(16):481. In Chem. Abstr. 1972, 76(1):1580.

Small, R. P. 1977. Vegetable Summary. Fla. Crop and Livestock Reporting Service, Orlando, Fla.

Snee, R. D. 1971. Design and analysis of mixture experiments. J. Quality Technol. 3(4):159.

Sokol, A. P. and Anokhina, V. I. 1973. New types of containers for salting watermelons. Tovarovedenie. 6:37. In Food Science Technol. Abstr. 1973, 5(10):1588.

Sokol, P. F. and Vasina, V. I. 1973. Change in sugar level in watermelon pulp as a function of different temperature conditions. Dokl. Vses. Akad. Sel'skokhoz Nauk. 7:8 In Chem. Abstr. 1973, 79(19):1141 39.

Soule,M.J.,Jr. and Harding, P. L. 1956. Changes in physical characters and chemical constituents of Haden mangos during ripening at 80°F. Fla. State Hort. Soc. 69:282.

Stafford, W. and Oke, O. L. 1977. Protein isolates form lesser known oilseeds from Nigeria. Nutr. Rep. Int. 16(6):813.

Stafford, W. L., Umoh, I. B., Ayalogu, E. O. and Oke, O. L. 1978. Lesser known oilseeds:nutritive value of the protein isolates. Nutr. Rep. Int. 18(1):69.

Stillings, B. R. and Hackler, L. R. 1966. Amino acid studies on the effect of fermentation time and heat-processing of tempeh. J. Food Sci. 30:1043.

Swern, D. 1964a. Reactions of fats and fatty acids. In "Bailey's Industrial Oil and Fat Products," 3rd ed., p. 55. Interscience Publishers, John Wiley and Sons, New York, London, Sydney.

Swern, D. 1964b. Sources, utilization, and classification of oils and fats. In "Bailey's Industrial Oil and Fat Product," 3rd ed., p. 153. Interscience Publishers, John Wiley and Sons, New York, London, Sydney.

Swern, D. 1964c. Composition and characteristics of individual fats and oils. In "Bailey's Industrial Oil and Fat Products," 3rd. ed., p. 165. Interscience Publishers, John Wiley and Sons, New York, London, Sydney.

Thorner, M. E. and Herzberg, R. J. 1970. Juices. In "Food Beverage Service Handbook. A Complete Guide to Hot and Cold Soft Drinks," p. 187. AVI Publishing Co., Inc. Westport, Conn.

Ting, S. V. and Deszyck, E. J. 1958. The internal color and carotenoid pigments of Florida red and pink grapefruit. Proc. Am. Soc. Hort. Sci. 71:271.

Tomes, J. L. Johnson, K. W. and Marie Hess. 1963. The carotene pigment content of certain red-fleshed watermelons. Proc. Am. Soc. Hort. Sci. 82:460.

Tomkins, M. D. and Pratt, G. B. 1959. Comparison of flavor evaluation methods for frozen citrus concentrate. Food Technol. 13:149.

Townsend, C. T., Sommers, I. I., Lamb, F. C. and Olson, N. A. 1956. "A Laboratory Manual for the Canning Industry," 2nd ed., National Canners Assoc. Research Laboratories, Washington, D.C.

Tressler, D. K. and Joslyn, M. A. 1961. "Fruits and Vegetable Juice Processing Technology," AVI Publishing Co., Inc. Westport, Conn.

Tressler, D. K. and Woodroof, J. G. 1976. Fruit beverages and purées. In "Food Products Formulatory vol. 3. Fruit, Vegetable and Nut Products," p. 1. AVI Publishing Co., Inc., Westport, Conn.

Umoh, I. B. and Oke, O. L. 1974. Nutritive value of some lesser known oilseeds in rats. Nutr. Dep. Int. 9(6):453.

USDA. 1968. United States Standards for grades of grapefruit juice. Consumer and Marketing Service, Washington, D.C.

USDA. 1970. United States Standards for grades of frozen concentrated grapefruit juice. Consumer and Marketing Service, Washington, D.C.

USDA. 1977. Agricultural Statistics, Government Printing Office, Washington, D.C.

Wall, G. B. 1978. Production and shipping of Florida watermelons. Proc. Fla. State Hort. Soc. In press.

Wang, C. F. 1940. Preparation of crystalline protein from seeds of watermelon, gourds, pumpkins,etc. Chinese J. Physiol. 15:231. In Chem. Abstr. 1940, 34(18):6330.

Watt, B. K. and Merrill, A. L. 1975. "Handbook of the Nutritional Contents of Foods," Dover Publications, Inc., New York.

Webster, J. E. and Romshe, F. A. 1951. Watermelon syrup; its composition and the composition of juice from which it was made. Proc. Am. Soc. Hort. Sci. 57:32.

Weisler, A. 1975. FDA regulation of food colors. Food Technol. 29(5):38.

Weiss, T. J. 1970. Basic processing of fats and oils. In "Food Oils and Uses," p. 47. AVI Publishing Co., Inc., Westport, Conn.

Wolf, W. J. and Cowan, J. C. 1975. Food uses of soybean proteins. In "Soybeans as a Food Source," Revised ed., p. 25. CRC Press, Cleveland, Ohio.

Woodroof, J. G. and Phillips, G. F. 1974. Types of non-carbonated beverages. In "Beverages: Carbonated and Noncarbonated," p. 368. AVI Publishing Co., Inc., Westport, Conn.

Yawger, E. S., Jr. 1942. Preparing watermelon juice for packaging in commercial containers such as cans or bottles. U.S. Pat. 2, 298, 328.

Yoo, Y. 1972. Flow behavior of soybean-rice aqueous mixture. Master's thesis, University of Florida, Gainesville, Fla.

Zeleny, L. and Coleman, D. A. 1938. Acidity in cereals and cereal products, its determination and significance. Cereal Chem. 15:580.

Zscheile, F. P., and J. S. Porter. 1947. Analytical methods for carotenes of Lycopersicon species and strains. Anal. Chem. 19:47.

# BIOGRAPHICAL SKETCH

Sim Sun Huor was born on October 11, 1938, at Kompong Cham, Cambodia. He graduated from his home-town secondary school in 1959. He entered the University of Florida in September 1960, and received a Bachelor of Science in Agriculture in April 1964, and a Master of Agriculture with major in Fruit Crops in December 1965. Upon returning home, he was employed by the Cambodian Department of Agriculture in the capacity of director of an agriculture pilot station, then Chief of Plant Protection Division. He came back to the University of Florida in June 1974 and received his Doctor of Philosophy with major in Horticultural Sciences (Food Science and Human Nutrition) in March 1979.

He is married to the former Yane Poc and they have 2 children, Vissett and Anita. Both are attending Williams Elementary School in Gainesville.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

E. M. Ahmed

E. M. Ahmed, Chairman
Professor of Food Science and
Human Nutrition

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

D. D. Gull

D. D. Gull
Associate Professor of Vegetable
Crops

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

P. V. Rao

P. V. Rao
Professor of Statistics

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

James Soule

J. Soule
Professor of Fruit Crops

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

S.V. Ting

S. V. Ting
Adjunct Professor of Food Science
and Human Nutrition

This dissertation was submitted to the Graduate Faculty of the College of Agriculture and to the Graduate Council, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

March, 1979

Jack L. Fry

Dean, College of Agriculture

Dean, Graduate School